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LASER ABSORPTION IN THE 5 MICRON BAND
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The Ohio State University
ElectroScience Laboratory
Department of Electrical Engineering
Columbus, Ohio 43212

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13. ABSTRACT

This report summarizes technical details of the work performed from June 23 to September 23, 1971. A detailed discussion of work performed at the Ohio State Univ. Electro-Science Laboratory is presented. This work consisted of atmospheric transmittance calculations near 5μm and the design of a laboratory experiment to determine the transmittance of CO laser radiation through synthetic atmospheres.

Computer programs have been written to calculate the molecular absorption due to atmospheric absorbers near 5μm. The type of calculations include computer plots of the calculated spectra, more accurate transmittance values at the frequencies of the CO laser emissions for horizontal paths, and transmittance values at the frequencies of the CO laser emissions for slant paths through the atmosphere. Preliminary calculations are presented with water vapor as the only atmospheric absorber considered.

The design of an experiment to measure the transmittance of the CO laser emissions through simulated atmospheres is described. Specific topics covered are the CO laser, selection of the emission lines to be measured, the multiple traversal cell, and the experimental procedure.

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LASER ABSORPTION IN THE 5 MICRON BAND

Dr. Ronald Long

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Principal Investigator: Dr. Ronald Long
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Project Engineer: James W. Cusack
Phone: 315 330-3443

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PUBLICATION REVIEW

This technical report has been reviewed and is approved.

James W Cusack

RADC Project Engineer

FOREWORD

This report, OSURF Report 3271-1, was prepared by The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering at Columbus, Ohio. Principal contributors to the report were Dr. D. L. Ford and Mr. G. L. Trusty. Research was conducted under Contract F30602-72-C-0016. Mr. James W. Cusack, RADC (OCSE), of Rome Air Development Center, Griffiss Air Force Base, New York, is the Project Engineer.

ABSTRACT

This report summarizes technical details of the work performed from June 23 to September 23, 1971. A detailed discussion of work performed at the Ohio State University ElectroScience Laboratory is presented. This work consisted of atmospheric transmittance calculations near 5 μm and the design of a laboratory experiment to determine the transmittance of CO laser radiation through synthetic atmospheres.

Computer programs have been written to calculate the molecular absorptance due to atmospheric absorbers near 5 μm. The type of calculations include computer plots of the calculated spectra, more accurate transmittance values at the frequencies of the CO laser emissions for horizontal paths, and transmittance values at the frequencies of the CO laser emissions for slant paths through the atmosphere. Preliminary calculations are presented with water vapor as the only atmospheric absorber considered.

The design of an experiment to measure the transmittance of the CO laser emissions through simulated atmospheres is described. Specific topics covered are the CO laser, selection of the emission lines to be measured, the multiple traversal cell, and the experimental procedure.

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I. INTRODUCTION

This is the first quarterly report on Contract Number F30602-72-C-0016 entitled "Laser Absorption Studies in the 5 Micron Band" for the period June 23, through September 20, 1971. The objectives of this contract are to perform laboratory measurements and theoretical computations in order to determine values of atmospheric transmittances at CO laser wavelengths. The technical accomplishments during this period are described in detail in this report.

The CO laser has a large number of laser emission frequencies near 2000 cm^{-1} (5 μm) which have been accurately measured by Mantz et al.[1] and Yardley.[2] Many potential applications of this laser depend upon a knowledge of the atmospheric attenuation of the laser output. Water vapor, carbon dioxide, nitrous oxide, methane, and ozone attenuate the laser emissions by molecular absorption in the atmosphere. The amount of attenuation for each of the laser's emission lines depends on the absorption lines' frequencies, strengths, half-widths and the concentration of each of the absorbers in the atmosphere. Also the attenuation depends on the temperature and pressure profiles of the atmosphere. If all of these parameters are known sufficiently accurately, useful estimates of the atmospheric transmittance of the laser emissions can be calculated using standard techniques. While the wavelengths of the CO laser emission lines are accurately known (0.006 cm^{-1}),[1] most of the water lines near 2000 cm^{-1}, as listed in the tables of Benedict and Calfee,[3] have an uncertainty in their positions of 0.05 cm^{-1}; however, for some lines the uncertainty may be as large as 2.0 cm^{-1}.

The half-widths of the absorption coefficient of water vapor lines at one atmosphere are on the order of 0.05 cm^{-1}. Thus the atmospheric transmittance is a rapidly varying function of the frequency, and therefore, the accuracy of the calculated transmittance at the laser frequencies is strongly dependent upon the position of the absorbing lines.

Two approaches to improve the predicted accuracy of transmittance through actual atmospheres at laser frequencies are available. Ideally the positions, strengths, half-widths and shapes of the lines for all molecular absorbers of the CO laser output should be determined. Since water vapor alone has several thousand absorption lines in this spectral region, an extensive program would be required. A more direct approach would be to measure the transmittance at CO wavelengths under representative conditions in the laboratory. The advantages of this latter approach include: 1) a less expensive program; 2) the data is obtained directly at the wavelengths of interest; 3) the data may be used to determine the accuracy with which the transmittance can be calculated using the presently available data on line positions, half-widths, strengths and shapes of the absorber lines.

Of course this approach requires a stable CO laser and a facility for long path length transmittance measurements.

Molecular scattering, aerosol scattering and aerosol absorption also attenuate the transmittance of the CO laser; however, the first is insignificant and the latter two are slowly varying functions of frequency. Thus a knowledge of the molecular absorption is most important in determining which CO laser lines are most useful in potential applications. Measurement of aerosol extinction is expected from a comparison of our laboratory measurements and outdoor CO measurements to be made at RADC.

During the work period of this report several computer programs were written to calculate the transmittance of CO laser radiant flux through model atmospheres. These programs are described in the next section. Simultaneously the preliminary design of the laboratory experiment to determine the transmittance of CO radiation through representative atmospheres was undertaken and it is described in the third section.

II. ABSORPTANCE CALCULATIONS

Portions of the computer programs to be discussed were developed under another Contract (F33615-69-C-1807) and modified under the current contract.

Computer programs were written which give, as output, information concerning theoretical molecular absorption in the spectral region of the CO laser lines. The programs give three basic forms of output which will be discussed separately.

Common to all the programs is the method for calculating the absorption at any frequency. This method employs a subroutine called ABSCOE which is a modified version of the one developed by Deutschman and Calfee.[4] This subroutine calculates the absorption coefficient k_ν at frequency ν where k_ν is defined by the extinction equation;

$$(1) \qquad I_\nu = I_{o_\nu} \exp(-k_\nu w)$$

Here $I_{o\nu}$ and I_ν are the incident and output intensities respectively and w is the absorber concentration.

For all computations up to the present time a Lorentz line shape has been assumed, using

$$(2) \qquad k_\nu = \frac{S}{\pi} \frac{\alpha}{(\nu-\nu_o)^2 - \alpha^2}$$

where S is the line intensity, α is the line halfwidth and ν_o is the center frequency of the line. This equation is used in conjunction with those necessary for the temperature and pressure corrections for the variables involved, viz:

$$(3) \qquad S = S_o \left(\frac{T_o}{T}\right)^m \exp\left(-\frac{E''}{k}\frac{T_o - T}{T_o T}\right)$$

and

$$(4) \qquad \alpha = \alpha_o \left(\frac{P}{P_o}\right)\left(\frac{T_o}{T}\right)^n$$

where T_o and P_o refer to a reference temperature and pressure, E" is the lower energy level of the transition and k is the Boltzmann constant. The exponent m varies with absorber and n is a function of absorber broadening gas and frequency. For water vapor the values of m and n have been chosen to be 1.5 and 0.62 respectively.

A note here about units is in order. The H_2O line data[3] used gives the halfwidth in units of cm^{-1}/atm, i.e., the data given is actually the α_o/P_o term in Eq. (4) with P_o = 1 atm. The line intensity S is given in units of $cm^{-1}/(gm\ cm^{-2})$. Since intensity is defined by

$$S = \int_{-\infty}^{\infty} k_\nu d\nu,$$

we get k in units of $1/(gm\ cm^{-2})$. By dimensional analysis alone this says the absorber concentration w must be in units of $gm\ cm^{-2}$ since the exponent in the extinction equation must be dimensionless. However since the density of water is 1 gm/cm^3, the absorber concentration can be written as pr-cm. A discussion of various associated units is given by McCoy.[5]

Equations (2), (3) and (4) give the absorption coefficient at frequency ν due to one absorption line centered at frequency ν_o. However many lines near frequency ν may contribute appreciably to the value of k_ν. Therefore the resultant absorption coefficient due to all lines near ν is found as

$$(5) \qquad k = \sum_{\nu_o} k_\nu = \sum_{\nu_o} \frac{S_{\nu_o}}{\pi} \frac{\alpha_{\nu_o}}{(\nu-\nu_o)^2 + \alpha_{\nu_o}^2}$$

Due to the $(\nu-\nu_0)^2$ term in the denominator, the contributions of lines far from ν_0 become negligible. Note that the point where this occurs is also a function of S_{ν_0} and α_{ν_0}.

The subroutine ABSCOE uses a variable called BOUND to determine how far on either side of frequency ν to go when including lines; i.e., lines within the region ν-BOUND $\leq \nu <$ ν+BOUND are included. This variable and the variable SLOW, which designates the weakest absorption line to be considered, are both chosen such that a reasonable compromise between high accuracy and low computer time is reached.

The first computer program produces, for a given frequency range, pressure, temperature, absorber concentration and a plot of the absorption spectrum. Also on the plot is a designation of the location of given laser lines. Figures 1 and 2 give examples of these plots for two different sets of conditions.

A second program prints out, for any given frequency (in our case, any given laser line), the absorption coefficient and the transmittance at given distances. Pressure, temperature and amount of absorber are, of course, also inputs to this program. Table 1 gives a few examples of the output of this program which has been put in a form to correspond to weather data and test sites at RADC.

The third program is somewhat more complex. The input to this program is pressure, temperature and absorber concentration as a function of altitude, i.e., a given atmospheric model. Output is produced for any given number of laser line frequencies and provides the information needed to calculate slant path transmittance for those laser lines.

The approach to the problem is to calculate the extinction coefficient at each given altitude. (The current atmospheric models have about 8 points of data for the 0-10 km altitude range.) A polynomial is then fit to these results. This polynomial is in turn used to calculate vertical absorptance due to the variable extinction coefficient. The program takes the exact equation for transmittance

$$(6) \qquad T = \exp(- \int_0^h B(x)\, dx)$$

as

$$(7) \qquad T = \exp(- \sum_0^h B(x)\, \Delta x)$$

where B is related to k by

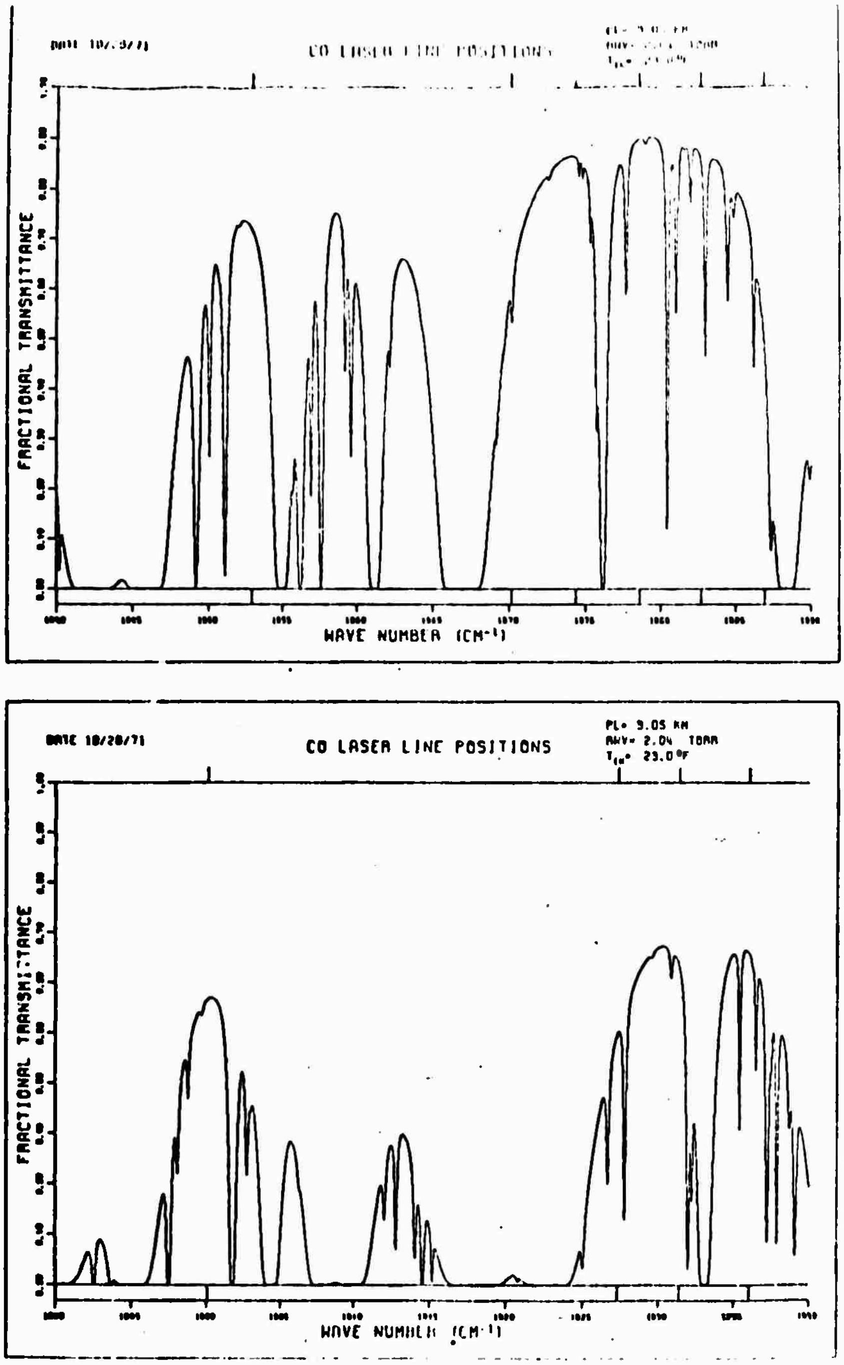

Fig. 1. Calculated horizontal atmospheric transmittance in the region 1890 to 1940 cm^{-1} through a 3.05 km path in which the absorbing gas is 2.04 torr of water vapor. The temperature and amount of water vapor present are those occurring at Rome, New York, January 6, 1971. Fewer water lines were used to calculate the transmittance than was used in the calculations for the same conditions listed in Table 1 to limit the computer time necessary to produce this plot.

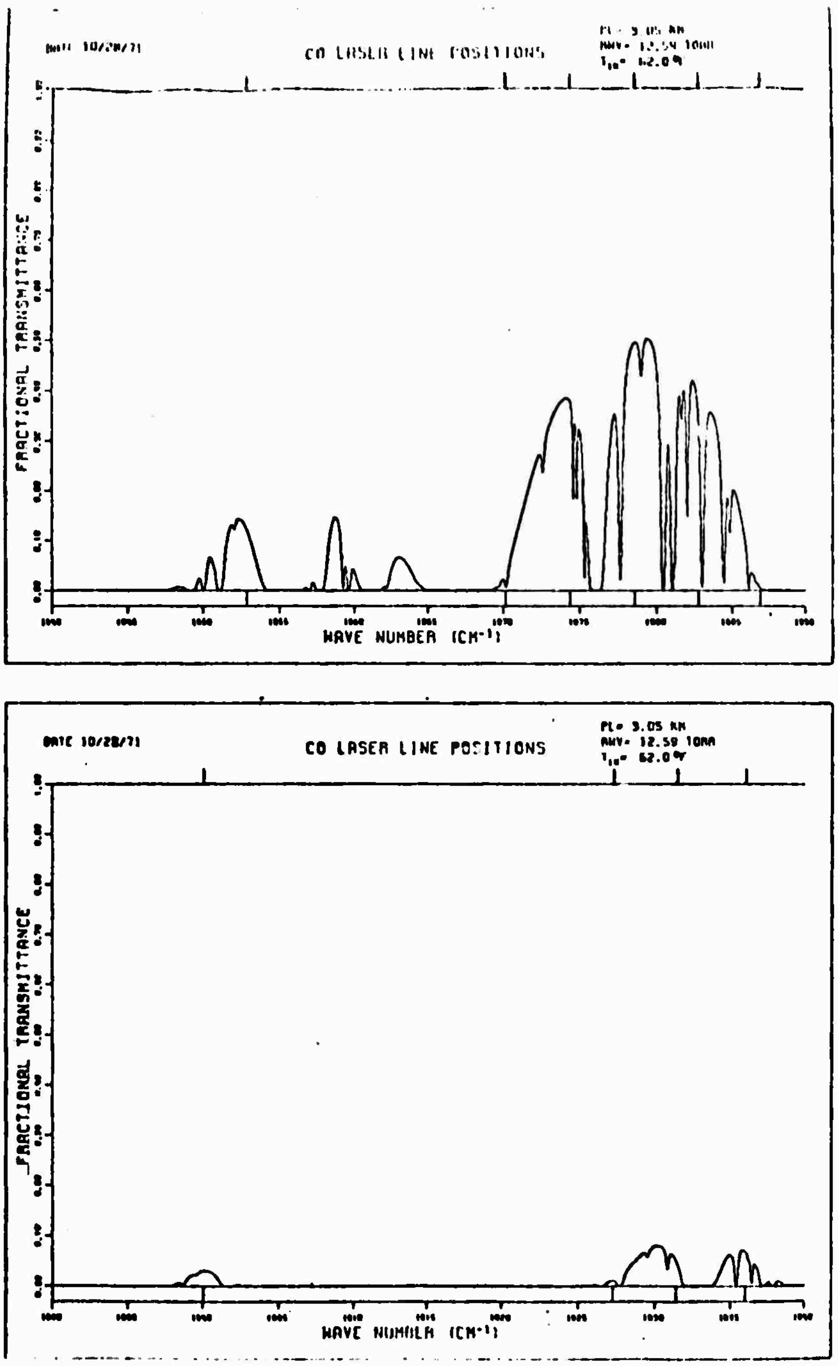

Fig. 2. Calculated horizontal atmospheric transmittance in the region 1890 to 1940 cm^{-1} through a 3.05 km path in which the absorbing gas is 12.59 torr of water vapor. The temperature and the amount of water vapor present are those occurring at Rome, New York, July 12, 1971. Fewer water lines were used to calculate the transmittance than was used in the calculations for the same conditions listed in Table 1 to limit the computer time necessary to produce this plot.

MONTH YEAR DAY
1 71 19

TIME 400 TEMP=-19 DEG F RH= 64 RWV= .22 TORR

WAVENMBR 1/CM	EXT COEF 1/KM	.62KM TRANS.	1.23KM TRANS.	1.85KM TRANS.	2.45KM TRANS.	3.05KM TRANS.	20.00KM TRANS.	50.00KM TRANS.	68.00KM TRANS.
1978.609	.003	1.00E 0	1.00E 0	.99E 0	.99E 0	.99E 0	.94E 0	.85E 0	.80E 0
1974.357	.005	1.00E 0	.99E 0	.99E 0	.99E 0	.99E 0	.91E 0	.79E 0	.72E 0
1982.766	.005	1.00E 0	.99E 0	.99E 0	.99E 0	.98E 0	.90E 0	.78E 0	.71E 0
1952.889	.011	.99E 0	.99E 0	.98E 0	.97E 0	.97E 0	.81E 0	.59E 0	.48E 0
1936.003	.014	.99E 0	.98E 0	.98E 0	.97E 0	.96E 0	.76E 0	.50E 0	.39E 0
1931.361	.014	.99E 0	.98E 0	.97E 0	.97E 0	.96E 0	.75E 0	.49E 0	.37E 0
1900.044	.021	.99E 0	.97E 0	.96E 0	.95E 0	.94E 0	.66E 0	.35E 0	.24E 0
1970.159	.016	.99E 0	.98E 0	.97E 0	.96E 0	.95E 0	.72E 0	.44E 0	.33E 0
1927.283	.024	.99E 0	.97E 0	.96E 0	.94E 0	.93E 0	.62E 0	.31E 0	.20E 0
1986.918	.022	.99E 0	.97E 0	.96E 0	.95E 0	.93E 0	.64E 0	.33E 0	.22E 0

TIME 1300 TEMP= 1 DEG F RH= 78 RWV= .78 TORR

WAVENMBR 1/CM	EXT COEF 1/KM	.62KM TRANS.	1.23KM TRANS.	1.85KM TRANS.	2.45KM TRANS.	3.05KM TRANS.	20.00KM TRANS.	50.00KM TRANS.	68.00KM TRANS.
1976.609	.013	.99E 0	.98E 0	.98E 0	.97E 0	.96E 0	.78E 0	.53E 0	.43E 0
1974.357	.016	.99E 0	.98E 0	.97E 0	.96E 0	.95E 0	.70E 0	.41E 0	.29E 0
1982.766	.019	.99E 0	.98E 0	.96E 0	.95E 0	.94E 0	.68E 0	.38E 0	.27E 0
1952.889	.040	.98E 0	.95E 0	.93E 0	.91E 0	.89E 0	.45E 0	.14E 0	.67E -1
1936.003	.051	.97E 0	.94E 0	.91E 0	.88E 0	.86E 0	.36E 0	.78E -1	.31E -1
1931.361	.054	.97E 0	.94E 0	.90E 0	.88E 0	.85E 0	.34E 0	.66E -1	.25E -1
1900.044	.075	.95E 0	.91E 0	.87E 0	.83E 0	.79E 0	.22E 0	.23E -1	.60E -2
1970.159	.065	.96E 0	.92E 0	.89E 0	.85E 0	.82E 0	.27E 0	.38E -1	.12E -1
1927.283	.083	.95E 0	.90E 0	.85E 0	.81E 0	.76E 0	.17E 0	.12E -1	.25E -2
1986.918	.086	.95E 0	.90E 0	.85E 0	.81E 0	.77E 0	.18E 0	.13E -1	.28E -2

TABLE 1a
CO LASER TRANSMITTANCE FOR 10 LASER LINE AND 8 HORIZONTAL PATHLENGTHS FOR ATMOSPHERIC CONDITIONS NOTED.

MONTH YEAR DAY
1 71 4

TIME 400 TEMP= 25 DEG F RH= 84 RWV= 2.77 TORR

WAVENMBR 1/CM	EXT COEF 1/KM	.62KM TRANS.	1.23KM TRANS.	1.85KM TRANS.	2.45KM TRANS.	3.05KM TRANS.	20.00KM TRANS.	50.00KM TRANS.	68.00KM TRANS.
1976.609	.046	.97E 0	.94E 0	.92E 0	.89E 0	.87E 0	.40E 0	.98E -1	.43E -1
1974.357	.067	.96E 0	.92E 0	.88E 0	.85E 0	.02E 0	.26E 0	.36E -1	.11E -1
1962.7[illegible]6	.074	.96E 0	.91E 0	.87E 0	.84E 0	.00E 0	.25E 0	.25E -1	.67E -2
1952.889	.145	.91E 0	.84E 0	.76E 0	.70E 0	.64E 0	.55E -1	.70E -3	.51E -4
1936.003	.188	.89E 0	.79E 0	.71E 0	.63E 0	.56E 0	.23E -1	.84E -4	.29E -5
1931.381	.201	.86E 0	.78E 0	.69E 0	.61E 0	.54E 0	.18E -1	.42E -4	.11E -5
1900.044	.266	.65E 0	.72E 0	.61E 0	.52E 0	.44E 0	.49E -2	.17E -5	.14E -7
1970.159	.260	.85E 0	.73E 0	.62E 0	.53E 0	.45E 0	.55E -2	.22E -5	.20E -7
1927.283	.322	.82E 0	.67E 0	.55E 0	.45E 0	.37E 0	.16E -2	.10E -6	.30E -9
1986.918	.333	.81E 0	.66E 0	.54E 0	.44E 0	.36E 0	.13E -2	.59E -7	.15E -9

TIME 1300 TEMP= 30 DEG F RH= 91 RWV= 3.74 TORR

WAVENMBR 1/CM	EXT COEF 1/KM	.62KM TRANS.	1.23KM TRANS.	1.85KM TRANS.	2.45KM TRANS.	3.05KM TRANS.	20.00KM TRANS.	50.00KM TRANS.	68.00KM TRANS.
1976.609	.054	.96E 0	.92E 0	.89E 0	.86E 0	.82E 0	.28E 0	.42E -1	.13E -1
1974.357	.091	.95E 0	.89E 0	.84E 0	.80E 0	.76E 0	.16E 0	.10E -1	.20E -2
1962.7[illegible]6	.101	.94E 0	.88E 0	.83E 0	.78E 0	.73E 0	.13E 0	.65E -2	.10E -2
1952.889	.198	.88E 0	.78E 0	.69E 0	.62E 0	.55E 0	.19E -1	.49E -4	.14E -5
1936.003	.257	.85E 0	.73E 0	.62E 0	.53E 0	.46E 0	.59E -2	.27E -5	.26E -7
1931.381	.276	.84E 0	.71E 0	.60E 0	.51E 0	.43E 0	.40E -2	.10E -5	.71E -8
1900.044	.361	.80E 0	.64E 0	.51E 0	.41E 0	.33E 0	.73E -3	.14E -7	.22E-10
1970.159	.363	.80E 0	.64E 0	.51E 0	.41E 0	.33E 0	.71E -3	.13E -7	.19E-10
1927.283	.440	.76E 0	.58E 0	.44E 0	.34E 0	.26E 0	.15E -3	.27E -9	.99E-13
1986.918	.459	.75E 0	.57E 0	.43E 0	.33E 0	.25E 0	.10E -3	.11E -9	.27E-13

TABLE 1b
CO LASER TRANSMITTANCE FOR 10 LASER LINE AND 8 HORIZONTAL PATHLENGTHS FOR ATMOSPHERIC CONDITIONS NOTED.

MONTH YEAR DAY
7 71 2

TIME 400 TEMP= 62 DEG F RH= 96 RWV= 13.67 TORR

WAVENMBR 1/CM	EXT COEF 1/KM	.62KM TRANS.	1.23KM TRANS.	1.85KM TRANS.	2.45KM TRANS.	3.05KM TRANS.	20.00KM TRANS.	50.00KM TRANS.	68.00KM TRANS.
1978.609	.255	.85E 0	.73E 0	.63E 0	.54E 0	.46E 0	.62E -2	.30E -5	.30E -7
1974.357	.368	.80E 0	.64E 0	.51E 0	.41E 0	.32E 0	.63E -3	.10E -7	.13E-10
1982.766	.418	.77E 0	.60E 0	.46E 0	.36E 0	.28E 0	.28E -3	.83E -9	.44E-12
1952.889	.781	.62E 0	.38E 0	.24E 0	.15E 0	.92E -1	.16E -6	.11E-16	.86E-23
1936.003	1.020	.53E 0	.28E 0	.15E 0	.83E -1	.44E -1	.14E -8	.72E-22	.78E-30
1931.381	1.102	.51E 0	.26E 0	.13E 0	.68E -1	.35E -1	.27E -9	.12E-23	.29E-32
1900.044	1.373	.43E 0	.18E 0	.79E -1	.35E -1	.15E -1	.12E-11	.15E-29	.00E 1
1970.159	1.635	.36E 0	.13E 0	.49E -1	.18E -1	.68E -2	.63E-14	.00E 1	.00E 1
1927.283	1.740	.34E 0	.12E 0	.40E -1	.14E -1	.49E -2	.77E-15	.00E 1	.00E 1
1986.918	1.914	.31E 0	.95E -1	.29E -1	.93E -2	.29E -2	.24E-16	.00E 1	.00E 1

TIME 1300 TEMP= 62 DEG F RH= 96 RWV= 13.67 TORR

WAVENMBR 1/CM	EXT COEF 1/KM	.62KM TRANS.	1.23KM TRANS.	1.85KM TRANS.	2.45KM TRANS.	3.05KM TRANS.	20.00KM TRANS.	50.00KM TRANS.	68.00KM TRANS.
1978.609	.255	.85E 0	.73E 0	.63E 0	.54E 0	.46E 0	.62E -2	.30E -5	.30E -7
1974.357	.368	.80E 0	.64E 0	.51E 0	.41E 0	.32E 0	.63E -3	.10E -7	.13E-10
1982.766	.418	.77E 0	.60E 0	.46E 0	.36E 0	.28E 0	.23E -3	.83E -9	.44E-12
1952.889	.781	.62E 0	.38E 0	.24E 0	.15E 0	.92E -1	.16E -6	.11E-16	.86E-23
1936.003	1.020	.53E 0	.28E 0	.15E 0	.83E -1	.44E -1	.14E -8	.72E-22	.78E-30
1931.381	1.102	.51E 0	.26E 0	.13E 0	.68E -1	.35E -1	.27E -9	.12E-23	.29E-32
1900.044	1.373	.43E 0	.18E 0	.79E -1	.35E -1	.15E -1	.12E-11	.15E-29	.00E 1
1970.159	1.635	.36E 0	.13E 0	.49E -1	.18E -1	.68E -2	.63E-14	.00E 1	.00E 1
1927.283	1.740	.34E 0	.12E 0	.40E -1	.14E -1	.49E -2	.77E-15	.00E 1	.00E 1
1986.918	1.914	.31E 0	.95E -1	.29E -1	.93E -2	.29E -2	.24E-16	.00E 1	.00E 1

TABLE 1c
CO LASER TRANSMITTANCE FOR 10 LASER LINE AND 8 HORIZONTAL PATHLENGTHS FOR ATMOSPHERIC CONDITIONS NOTED.

MONTH YEAR DAY
7 71 23

TIME 400 TEMP= 64 DEG F RH= 75 RWV= 11.45 TORR

WAVENMBR 1/CM	EXT COEF 1/KM	.62KM TRANS.	1.23KM TRANS.	1.85KM TRANS.	2.45KM TRANS.	3.05KM TRANS.	20.00KM TRANS.	50.00KM TRANS.	60.00KM TRANS.
1978.609	.211	.88E 0	.77E 0	.68E 0	.60E 0	.52E 0	.15E -1	.26E -4	.57E -6
1974.357	.306	.83E 0	.69E 0	.57E 0	.47E 0	.39E 0	.22E -2	[illegible]	.90E -9
1982.766	.349	.81E 0	.65E 0	.56E 0	.43E 0	.34E 0	.94E -3	[illegible]	.51E-10
1952.889	.648	.67E 0	.45E 0	.30E 0	.21E 0	.14E 0	.24E -5	.86E-14	.74E-19
1936.003	.846	.59E 0	.35E 0	.21E 0	.13E 0	.75E -1	.45E -7	.42E-18	.10E-24
1931.381	.915	.57E 0	.32E 0	.18E 0	.11E 0	.61E -1	.11E -7	.14E-19	.95E-27
1900.044	1.137	.50E 0	.25E 0	.12E 0	.62E -1	.31E -1	.16E -9	.20E-24	.26E-63
1970.159	1.373	.43E 0	.18E 0	.79E -1	.35E -1	.15E -1	.12E-11	.15E-29	.00E 1
1927.283	1.444	.41E 0	.17E 0	.70E -1	.29E -1	.12E -1	.29E-12	.45E-31	.60E 1
1986.918	1.593	.37E 0	.14E 0	.55E -1	.20E -1	.77E -2	.15E-13	.25E-34	.00E 1

TIME 1300 TEMP= 84 DEG F RH= 50 RWV= 14.86 TORR

WAVENMBR 1/CM	EXT COEF 1/KM	.62KM TRANS.	1.23KM TRANS.	1.85KM TRANS.	2.45KM TRANS.	3.05KM TRANS.	20.00KM TRANS.	50.00KM TRANS.	60.00KM TRANS.
1978.609	.285	.84E 0	.70E 0	.59E 0	.50E [illegible]	.42E 0	.33E -2	.64E -6	.38E -8
1974.357	.417	.77E 0	.60E 0	.46E 0	.36E 0	.23E 0	.24E -3	.87E -9	.48E-12
1982.766	.480	.74E 0	.55E 0	.41E 0	.31E 0	.23E 0	.68E -4	.38E-10	.68E-14
1952.889	.864	.59E 0	.34E 0	.20E 0	.12E 0	.71E -1	.31E -7	.17E-18	.30E-25
1936.003	1.139	.49E 0	.25E 0	.12E 0	.62E -1	.31E -1	.13E -9	.18E-24	.25E-63
1931.381	1.232	.47E 0	.22E 0	.10E 0	.49E -1	.23E -1	.20E-10	.10E-26	.00E 1
1900.044	1.494	.40E 0	.16E 0	.63E -1	.26E -1	.10E -1	.11E-12	.37E-32	.00E 1
1970.159	2.030	.29E 0	.82E -1	.24E -1	.70E -2	.20E -2	.23E-17	.00E 1	.00E 1
1927.283	1.936	.30E 0	.92E -1	.28E -1	.88E -2	.27E -2	.15E-16	.00E 1	.00E 1
1986.918	2.194	.26E 0	.67E -1	.17E -1	.47E -2	.12E -2	.89E-19	.00E 1	.00E 1

TABLE 1d
CO LASER TRANSMITTANCE FOR 10 LASER LINE AND 8 HORIZONTAL PATHELENGTHS FOR ATMOSPHERIC CONDITIONS NOTED.

(8) $$B = \frac{k_\nu \cdot w}{L}$$

where L is a unit length corresponding to the units of Δx. Currently Δx is taken to be 10 meters, i.e., it is assumed that a constant extinction coefficient exists for each 10 meter altitude increment.

Table 2 gives the atmosphere model for 30°N latitude for July.[6] Table 3 gives the output of the program for that model for 10 laser lines. Remembering that only H_2O absorption is taken into account, the tables can be used to easily compute the expected transmittance of any slant path between any two altitudes between sea level and ten km.

Referring to the Fig. 3, shown below,

$$T_{\Delta h} = \exp - [\text{OPT. THICK. } (h_2) - \text{OPT. THICK. } (h_1)] \cdot \sec \theta$$

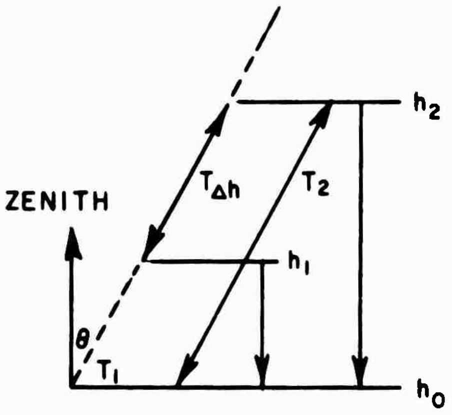

Fig. 3. Relationship of parameters for use in calculation transmittance along slant paths.

where θ is the zenith angle of the path.

TABLE 2

ATMOSPHERIC MODEL FOR 30°N LATITUDE, JULY

ALTITUDE METER	TEMPERATURE DEG K	PRESSURE* ATM	H2O PRESS. TORR
0.	301.150	1.1191	22.5900
1000.	293.650	.9543	11.6900
2000.	288.150	.8348	7.6500
3000.	282.650	.7336	5.3400
4000.	277.150	.6407	3.0200
6000.	266.150	.4920	1.0600
8000.	252.150	.3760	.3570
10000.	238.150	.2839	.0720

*This pressure is the effective pressure for water vapor. It accounts for the fact that the water vapor continuum depends much more on self-broadening due to water vapor molecules than broadening due to other atmospheric molecules.

At the bottom of each table the coefficients for the polynomial discussed above are listed.

The figures and tables presented in this section are only samples of the theoretical calculations to be made. For example the slant path calculations will be extended to cover 10 atmospheric models. For all the programs additional molecular absorbers, such as CO_2, will be added.

III. DESIGN OF THE EXPERIMENT TO MEASURE CO LASER EMISSION TRANSMITTANCE THROUGH SIMULATED ATMOSPHERES

Briefly the experiment consists of a CO laser whose output passes through a multiple traversal absorption cell. The ratio of the energy transmitted through the "filled" cell to the energy transmitted through the evacuated cell is measured for each CO laser emission line. The concentration of the absorbers in the cell, the total pressure, the optical path length of radiant flux through the cell and the particular laser lines to be used are selected after study of the results of the computed transmittances for different values of these parameters.

NOT REPRODUCIBLE

LASER LINE AT 1970.609

ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)	ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)
0.	4.796E -1	6.191E -1	0.000E 0				
100.	4.328E -1	6.487E -1	4.579E -2	5100.	1.743E -2	9.827E -1	6.533E -1
200.	3.929E -1	6.751E -1	8.722E -2	5200.	1.624E -2	9.839E -1	6.550E -1
300.	3.586E -1	6.987E -1	1.249E -1	5300.	1.512E -2	9.850E -1	6.566E -1
400.	3.289E -1	7.197E -1	1.594E -1	5400.	1.409E -2	9.860E -1	6.581E -1
500.	3.031E -1	7.385E -1	1.911E -1	5500.	1.312E -2	9.870E -1	6.594E -1
600.	2.804E -1	7.555E -1	2.204E -1	5600.	1.222E -2	9.879E -1	6.607E -1
700.	2.604E -1	7.708E -1	2.475E -1	5700.	1.138E -2	9.887E -1	6.619E -1
800.	2.426E -1	7.846E -1	2.727E -1	5800.	1.061E -2	9.894E -1	6.630E -1
900.	2.267E -1	7.972E -1	2.963E -1	5900.	9.884E -3	9.902E -1	6.640E -1
1000.	2.124E -1	8.087E -1	3.183E -1	6000.	9.213E -3	9.908E -1	6.650E -1
1100.	1.994E -1	8.192E -1	3.389E -1	6100.	8.590E -3	9.914E -1	6.659E -1
1200.	1.877E -1	8.289E -1	3.583E -1	6200.	8.011E -3	9.920E -1	6.667E -1
1300.	1.769E -1	8.379E -1	3.766E -1	6300.	7.473E -3	9.926E -1	6.675E -1
1400.	1.669E -1	8.462E -1	3.938E -1	6400.	6.973E -3	9.931E -1	6.682E -1
1500.	1.578E -1	8.540E -1	4.101E -1	6500.	6.509E -3	9.935E -1	6.689E -1
1600.	1.492E -1	8.614E -1	4.255E -1	6600.	6.078E -3	9.939E -1	6.695E -1
1700.	1.413E -1	8.682E -1	4.400E -1	6700.	5.677E -3	9.943E -1	6.701E -1
1800.	1.338E -1	8.747E -1	4.538E -1	6800.	5.304E -3	9.947E -1	6.706E -1
1900.	1.268E -1	8.809E -1	4.669E -1	6900.	4.957E -3	9.951E -1	6.712E -1
2000.	1.202E -1	8.867E -1	4.793E -1	7000.	4.633E -3	9.954E -1	6.716E -1
2100.	1.139E -1	8.923E -1	4.910E -1	7100.	4.332E -3	9.957E -1	6.721E -1
2200.	1.080E -1	8.976E -1	5.021E -1	7200.	4.050E -3	9.960E -1	6.725E -1
2300.	1.025E -1	9.027E -1	5.127E -1	7300.	3.788E -3	9.962E -1	6.729E -1
2400.	9.694E -2	9.076E -1	5.227E -1	7400.	3.542E -3	9.965E -1	6.733E -1
2500.	9.180E -2	9.123E -1	5.321E -1	7500.	3.311E -3	9.967E -1	6.736E -1
2600.	8.686E -2	9.168E -1	5.411E -1	7600.	3.095E -3	9.969E -1	6.739E -1
2700.	8.210E -2	9.211E -1	5.496E -1	7700.	2.892E -3	9.971E -1	6.742E -1
2800.	7.769E -2	9.254E -1	5.576E -1	7800.	2.702E -3	9.973E -1	6.745E -1
2900.	7.339E -2	9.292E -1	5.652E -1	7900.	2.522E -3	9.975E -1	6.748E -1
3000.	6.927E -2	9.331E -1	5.723E -1	8000.	2.353E -3	9.977E -1	6.750E -1
3100.	6.534E -2	9.367E -1	5.791E -1	8100.	2.193E -3	9.978E -1	6.752E -1
3200.	6.158E -2	9.403E -1	5.854E -1	8200.	2.041E -3	9.980E -1	6.755E -1
3300.	5.799E -2	9.437E -1	5.914E -1	8300.	1.898E -3	9.981E -1	6.757E -1
3400.	5.456E -2	9.469E -1	5.971E -1	8400.	1.762E -3	9.982E -1	6.758E -1
3500.	5.130E -2	9.500E -1	6.024E -1	8500.	1.633E -3	9.984E -1	6.760E -1
3600.	4.818E -2	9.530E -1	6.074E -1	8600.	1.510E -3	9.985E -1	6.762E -1
3700.	4.523E -2	9.558E -1	6.120E -1	8700.	1.394E -3	9.986E -1	6.763E -1
3800.	4.242E -2	9.585E -1	6.164E -1	8800.	1.283E -3	9.987E -1	6.765E -1
3900.	3.975E -2	9.610E -1	6.206E -1	8900.	1.178E -3	9.988E -1	6.766E -1
4000.	3.722E -2	9.635E -1	6.244E -1	9000.	1.078E -3	9.989E -1	6.767E -1
4100.	3.483E -2	9.658E -1	6.280E -1	9100.	9.829E -4	9.990E -1	6.768E -1
4200.	3.257E -2	9.680E -1	6.314E -1	9200.	8.928E -4	9.991E -1	6.769E -1
4300.	3.044E -2	9.700E -1	6.346E -1	9300.	8.076E -4	9.992E -1	6.770E -1
4400.	2.843E -2	9.720E -1	6.375E -1	9400.	7.272E -4	9.993E -1	6.770E -1
4500.	2.654E -2	9.738E -1	6.403E -1	9500.	6.515E -4	9.993E -1	6.771E -1
4600.	2.477E -2	9.755E -1	6.428E -1	9600.	5.905E -4	9.994E -1	6.772E -1
4700.	2.310E -2	9.772E -1	6.453E -1	9700.	5.141E -4	9.995E -1	6.772E -1
4800.	2.154E -2	9.787E -1	6.475E -1	9800.	4.524E -4	9.995E -1	6.773E -1
4900.	2.008E -2	9.801E -1	6.496E -1	9900.	3.954E -4	9.996E -1	6.773E -1
5000.	1.871E -2	9.815E -1	6.515E -1	10000.	3.437E -4	9.997E -1	6.774E -1

THE COEFFICIENTS FOR THE POLYNOMIAL FIT ARE

-7.3489E -1 -1.0573E -3 3.2014E -7 -8.6711E-11 9.8070E-15 -4.0043E-19

TABLE 3a

CO LASER LINE TRANSMITTANCE FOR 30° N LATITUDE. JULY. ABSORPTANCE DUE TO WATER VAPOR ONLY.

LASER LINE AT 1974.357

ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)	ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)
0.	6.896E [illegible]	5.018E -1	0.000E 0				
100.	6.229E -1	5.364E -1	6.587E -2	5100.	2.630E -2	9.740E -1	9.507E -1
200.	5.659E -1	5.678E -1	1.255E -1	5200.	2.452E -2	9.758E -1	9.533E -1
300.	5.170E -1	5.963E -1	1.799E -1	5300.	2.287E -2	9.774E -1	9.556E -1
400.	4.746E -1	6.221E -1	2.296E -1	5400.	2.132E -2	9.789E -1	9.579E -1
500.	4.377E -1	6.455E -1	2.754E -1	5500.	1.988E -2	9.803E -1	9.599E -1
600.	4.052E -1	6.668E -1	3.176E -1	5600.	1.853E -2	9.816E -1	9.618E -1
700.	3.766E -1	6.862E -1	3.568E -1	5700.	1.720E -2	9.829E -1	9.636E -1
800.	3.512E -1	7.039E -1	3.933E -1	5800.	1.612E -2	9.840E -1	9.653E -1
900.	3.284E -1	7.201E -1	4.274E -1	5900.	1.503E -2	9.851E -1	9.669E -1
1000.	3.079E -1	7.350E -1	4.593E -1	6000.	1.402E -2	9.861E -1	9.683E -1
1100.	2.894E -1	7.487E -1	4.892E -1	6100.	1.309E -2	9.870E -1	9.697E -1
1200.	2.725E -1	7.615E -1	5.174E -1	6200.	1.221E -2	9.879E -1	9.710E -1
1300.	2.570E -1	7.733E -1	5.439E -1	6300.	1.140E -2	9.887E -1	9.722E -1
1400.	2.428E -1	7.844E -1	5.690E -1	6400.	1.065E -2	9.894E -1	9.733E -1
1500.	2.297E -1	7.940E -1	5.927E -1	6500.	9.948E -3	9.901E -1	9.743E -1
1600.	2.174E -1	8.046E -1	6.151E -1	6600.	9.296E -3	9.907E -1	9.753E -1
1700.	2.060E -1	8.138E -1	6.363E -1	6700.	8.689E -3	9.913E -1	9.762E -1
1800.	1.953E -1	8.226E -1	6.564E -1	6800.	8.124E -3	9.919E -1	9.770E -1
1900.	1.852E -1	8.309E -1	6.755E [illegible]	6900.	7.597E -3	9.924E -1	9.778E -1
2000.	1.757E -1	8.385E -1	6.936E -1	7000.	7.106E -3	9.929E -1	9.785E -1
2100.	1.667E -1	8.465E -1	7.107E -1	7100.	6.647E -3	9.934E -1	9.792E -1
2200.	1.581E -1	8.537E -1	7.270E -1	7200.	6.219E -3	9.938E -1	9.799E -1
2300.	1.500E -1	8.607E -1	7.425E -1	7300.	5.819E -3	9.942E -1	9.805E -1
2400.	1.422E -1	8.674E -1	7.571E -1	7400.	5.444E -3	9.946E -1	9.810E -1
2500.	1.346E -1	8.739E -1	7.710E -1	7500.	5.092E -3	9.949E -1	9.816E -1
2600.	1.277E -1	8.801E -1	7.842E -1	7600.	4.762E -3	9.952E -1	9.821E -1
2700.	1.209E -1	8.861E -1	7.966E -1	7700.	4.452E -3	9.956E -1	9.8[illegible]E -1
2800.	1.144E -1	8.919E -1	8.084E -1	7800.	4.160E -3	[illegible]53E -1	9.829E -1
2900.	1.082E -1	8.975E -1	8.196E -1	7900.	3.885E -3	[illegible]61E -1	9.833E -1
3000.	1.022E -1	9.028E -1	8.301E -1	8000.	3.626E -3	9.964E -1	9.837E -1
3100.	9.651E -2	9.080E -1	8.401E -1	8100.	3.380E -3	9.966E -1	9.841E -1
3200.	9.105E -2	9.130E -1	8.495E -1	8200.	3.148E -3	9.969E -1	9.844E -1
3300.	8.585E -2	9.176E -1	8.583E -1	8300.	2.928E -3	9.971E -1	9.847E -1
3400.	8.084E -2	9.223E -1	8.667E -1	8400.	2.719E -3	9.973E -1	9.850E -1
3500.	7.608E -2	9.267E -1	8.746E -1	8500.	2.521E -3	9.975E -1	9.853E -1
3600.	7.154E -2	9.310E -1	8.820E -1	8600.	2.332E -3	9.977E -1	9.855E -1
3700.	6.722E -2	9.350E -1	8.889E -1	8700.	2.153E -3	9.978E -1	9.857E -1
3800.	6.311E -2	9.388E -1	8.955E -1	8800.	1.992E -3	9.980E -1	9.859E -1
3900.	5.921E -2	9.425E -1	9.016E -1	8900.	1.820E -3	9.982E -1	9.861E -1
4000.	5.551E -2	9.460E -1	9.074E -1	9000.	1.666E -3	9.983E -1	9.863E -1
4100.	5.200E -2	9.493E -1	9.127E -1	9100.	1.519E -3	9.985E -1	9.865E -1
4200.	4.866E -2	9.525E -1	9.178E -1	9200.	1.381E -3	9.986E -1	9.866E -1
4300.	4.555E -2	9.555E -1	9.225E -1	9300.	1.249E -3	9.988E -1	9.867E -1
4400.	4.259E -2	9.583E -1	9.269E -1	9400.	1.125E -3	9.989E -1	9.869E -1
4500.	3.980E -2	9.610E -1	9.311E -1	9500.	1.008E -3	9.990E -1	9.870E -1
4600.	3.718E -2	9.635E -1	9.349E -1	9600.	8.987E -4	9.991E -1	9.871E -1
4700.	3.471E -2	9.659E -1	9.385E -1	9700.	7.963E -4	9.992E -1	9.871E -1
4800.	3.240E -2	9.681E -1	9.419E -1	9800.	7.010E -4	9.993E -1	9.872E -1
4900.	3.023E -2	9.702E -1	9.450E -1	9900.	6.129E -4	9.994E -1	9.873E -1
5000.	2.820E -2	9.722E -1	9.480E -1	10000.	5.319E -4	9.995E -1	9.873E -1

THE COEFFICIENTS FOR THE POLYNOMIAL FIT ARE

-3.7170E -1   -1.0482E -3   3.1865E -7   -8.6010E-11   9.7079E-15   -3.9620E-19

TABLE 3b

CO LASER LINE TRANSMITTANCE FOR 30^{O}N LATITUDE, JULY. ABSORPTANCE DUE TO WATER VAPOR ONLY.

NOT REPRODUCIBLE

LASER LINE AT 1982.766

ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)
0.	7.699E -1	4.631E -1	0.000E 0
100.	6.954E -1	4.989E -1	7.354E -2
200.	6.317E -1	5.317E -1	1.401E -1
300.	5.770E -1	5.616E -1	2.008E -1
400.	5.296E -1	5.888E -1	2.563E -1
500.	4.883E -1	6.137E -1	3.073E -1
600.	4.520E -1	6.363E -1	3.545E -1
700.	4.200E -1	6.571E -1	3.982E -1
800.	3.915E -1	6.760E -1	4.369E -1
900.	3.660E -1	6.935E -1	4.769E -1
1000.	3.431E -1	7.096E -1	5.125E -1
1100.	3.223E -1	7.245E -1	5.458E -1
1200.	3.034E -1	7.383E -1	5.772E -1
1300.	2.861E -1	7.512E -1	6.067E -1
1400.	2.701E -1	7.633E -1	6.346E -1
1500.	2.554E -1	7.746E -1	6.609E -1
1600.	2.417E -1	7.853E -1	6.859E -1
1700.	2.289E -1	7.954E -1	7.095E -1
1800.	2.169E -1	8.050E -1	7.318E -1
1900.	2.056E -1	8.142E -1	7.530E -1
2000.	1.949E -1	8.229E -1	7.730E -1
2100.	1.848E -1	8.312E -1	7.921E -1
2200.	1.753E -1	8.392E -1	8.101E -1
2300.	1.661E -1	8.469E -1	8.272E -1
2400.	1.574E -1	8.543E -1	8.435E -1
2500.	1.491E -1	8.615E -1	8.588E -1
2600.	1.412E -1	8.684E -1	8.734E -1
2700.	1.336E -1	8.750E -1	8.872E -1
2800.	1.263E -1	8.813E -1	9.002E -1
2900.	1.194E -1	8.875E -1	9.125E -1
3000.	1.127E -1	8.934E -1	9.241E -1
3100.	1.063E -1	8.991E -1	9.351E -1
3200.	1.002E -1	9.046E -1	9.455E -1
3300.	9.441E -2	9.099E -1	9.552E -1
3400.	8.885E -2	9.150E -1	9.644E -1
3500.	8.354E -2	9.196E -1	9.731E -1
3600.	7.849E -2	9.245E -1	9.812E -1
3700.	7.369E -2	9.290E -1	9.888E -1
3800.	6.912E -2	9.332E -1	9.960E -1
3900.	6.478E -2	9.373E -1	1.003E 0
4000.	6.067E -2	9.411E -1	1.009E 0
4100.	5.678E -2	9.448E -1	1.015E 0
4200.	5.310E -2	9.483E -1	1.020E 0
4300.	4.962E -2	9.516E -1	1.026E 0
4400.	4.635E -2	9.547E -1	1.030E 0
4500.	4.327E -2	9.577E -1	1.035E 0
4600.	4.037E -2	9.604E -1	1.039E 0
4700.	3.765E -2	9.631E -1	1.043E 0
4800.	3.510E -2	9.655E -1	1.047E 0
4900.	3.271E -2	9.678E -1	1.050E 0
5000.	3.047E -2	9.700E -1	1.053E 0

ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)
5100.	2.838E -2	9.720E -1	1.056E 0
5200.	2.643E -2	9.739E -1	1.059E 0
5300.	2.460E -2	9.757E -1	1.061E 0
5400.	2.291E -2	9.774E -1	1.064E 0
5500.	2.132E -2	9.789E -1	1.066E 0
5600.	1.985E -2	9.803E -1	1.068E 0
5700.	1.848E -2	9.817E -1	1.070E 0
5800.	1.721E -2	9.829E -1	1.072E 0
5900.	1.603E -2	9.841E -1	1.073E 0
6000.	1.493E -2	9.852E -1	1.075E 0
6100.	1.391E -2	9.862E -1	1.076E 0
6200.	1.296E -2	9.871E -1	1.078E 0
6300.	1.208E -2	9.880E -1	1.079E 0
6400.	1.126E -2	9.888E -1	1.080E 0
6500.	1.050E -2	9.896E -1	1.081E 0
6600.	9.791E -3	9.903E -1	1.082E 0
6700.	9.135E -3	9.909E -1	1.083E 0
6800.	8.524E -3	9.915E -1	1.084E 0
6900.	7.956E -3	9.921E -1	1.085E 0
7000.	7.427E -3	9.926E -1	1.086E 0
7100.	6.934E -3	9.931E -1	1.087E 0
7200.	6.474E -3	9.935E -1	1.087E 0
7300.	6.044E -3	9.940E -1	1.088E 0
7400.	5.643E -3	9.944E -1	1.088E 0
7500.	5.268E -3	9.947E -1	1.089E 0
7600.	4.916E -3	9.951E -1	1.089E 0
7700.	4.586E -3	9.954E -1	1.090E 0
7800.	4.276E -3	9.957E -1	1.090E 0
7900.	3.984E -3	9.960E -1	1.091E 0
8000.	3.710E -3	9.963E -1	1.091E 0
8100.	3.451E -3	9.966E -1	1.092E 0
8200.	3.206E -3	9.968E -1	1.092E 0
8300.	2.975E -3	9.970E -1	1.092E 0
8400.	2.757E -3	9.972E -1	1.092E 0
8500.	2.550E -3	9.975E -1	1.093E 0
8600.	2.354E -3	9.976E -1	1.093E 0
8700.	2.168E -3	9.978E -1	1.093E 0
8800.	1.991E -3	9.980E -1	1.093E 0
8900.	1.824E -3	9.982E -1	1.094E 0
9000.	1.666E -3	9.983E -1	1.094E 0
9100.	1.516E -3	9.985E -1	1.094E 0
9200.	1.374E -3	9.986E -1	1.094E 0
9300.	1.240E -3	9.988E -1	1.094E 0
9400.	1.115E -3	9.989E -1	1.094E 0
9500.	9.967E -4	9.990E -1	1.094E 0
9600.	8.863E -4	9.991E -1	1.095E 0
9700.	7.836E -4	9.992E -1	1.095E 0
9800.	6.883E -4	9.993E -1	1.095E 0
9900.	6.005E -4	9.994E -1	1.095E 0
10000.	5.200E -4	9.995E -1	1.095E 0

THE COEFFICIENTS FOR THE POLYNOMIAL FIT ARE

-2.6150E -1   -1.0490E -3   3.1720E -7   -8.5812E-11   9.6699E-15   -3.9416E-19

TABLE 3c

CO LASER LINE TRANSMITTANCE FOR 30^{O}N LATITUDE, JULY. ABSORPTANCE DUE TO WATER VAPOR ONLY.

NOT REPRODUCIBLE

LASER LINE AT 1952.688

ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)	ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)
0.	1.396E 0	2.477E -1	0.000E 0				
100.	1.260E 0	2.836E -1	1.333E -1	5100.	5.171E -2	9.496E -1	1.913E 0
200.	1.145E 0	3.183E -1	2.540E -1	5200.	4.819E -2	9.530E -1	1.918E 0
300.	1.045E 0	3.516E -1	3.638E -1	5300.	4.490E -2	9.561E -1	1.923E 0
400.	9.594E -1	3.831E -1	4.644E -1	5400.	4.183E -2	9.590E -1	1.927E 0
500.	8.844E -1	4.129E -1	5.569E -1	5500.	3.898E -2	9.618E -1	1.931E 0
600.	8.167E -1	4.410E -1	6.423E -1	5600.	3.632E -2	9.643E -1	1.935E 0
700.	7.606E -1	4.674E -1	7.215E -1	5700.	3.384E -2	9.667E -1	1.939E 0
800.	7.090E -1	4.922E -1	7.952E -1	5800.	3.154E -2	9.689E -1	1.942E 0
900.	6.628E -1	5.154E -1	8.640E -1	5900.	2.941E -2	9.710E -1	1.945E 0
1000.	6.212E -1	5.373E -1	9.283E -1	6000.	2.742E -2	9.730E -1	1.948E 0
1100.	5.836E -1	5.579E -1	9.887E -1	6100.	2.557E -2	9.748E -1	1.950E 0
1200.	5.494E -1	5.773E -1	1.046E 0	6200.	2.386E -2	9.764E -1	1.953E 0
1300.	5.180E -1	5.957E -1	1.099E 0	6300.	2.226E -2	9.780E -1	1.955E 0
1400.	4.892E -1	6.131E -1	1.150E 0	6400.	2.078E -2	9.794E -1	1.957E 0
1500.	4.625E -1	6.297E -1	1.197E 0	6500.	1.941E -2	9.808E -1	1.959E 0
1600.	4.377E -1	6.455E -1	1.242E 0	6600.	1.813E -2	9.820E -1	1.961E 0
1700.	4.145E -1	6.607E -1	1.285E 0	6700.	1.694E -2	9.832E -1	1.963E 0
1800.	3.928E -1	6.752E -1	1.326E 0	6800.	1.583E -2	9.843E -1	1.965E 0
1900.	3.723E -1	6.891E -1	1.364E 0	6900.	1.480E -2	9.853E -1	1.966E 0
2000.	3.530E -1	7.026E -1	1.400E 0	7000.	1.384E -2	9.863E -1	1.968E 0
2100.	3.347E -1	7.155E -1	1.435E 0	7100.	1.294E -2	9.871E -1	1.969E 0
2200.	3.174E -1	7.281E -1	1.467E 0	7200.	1.211E -2	9.880E -1	1.970E 0
2300.	3.009E -1	7.402E -1	1.496E 0	7300.	1.132E -2	9.887E -1	1.971E 0
2400.	2.851E -1	7.519E -1	1.528E 0	7400.	1.059E -2	9.895E -1	1.973E 0
2500.	2.701E -1	7.633E -1	1.556E 0	7500.	9.906E -3	9.901E -1	1.974E 0
2600.	2.557E -1	7.744E -1	1.582E 0	7600.	9.264E -3	9.908E -1	1.975E 0
2700.	2.419E -1	7.851E -1	1.607E 0	7700.	8.660E -3	9.914E -1	1.975E 0
2800.	2.288E -1	7.955E -1	1.630E 0	7800.	8.091E -3	9.919E -1	1.976E 0
2900.	2.162E -1	8.056E -1	1.653E 0	7900.	7.556E -3	9.925E -1	1.977E 0
3000.	2.041E -1	8.153E -1	1.674E 0	8000.	7.051E -3	9.930E -1	1.978E 0
3100.	1.926E -1	8.248E -1	1.694E 0	8100.	6.573E -3	9.934E -1	1.978E 0
3200.	1.816E -1	8.339E -1	1.712E 0	8200.	6.122E -3	9.939E -1	1.979E 0
3300.	1.711E -1	8.428E -1	1.730E 0	8300.	5.694E -3	9.943E -1	1.980E 0
3400.	1.610E -1	8.513E -1	1.747E 0	8400.	5.288E -3	9.947E -1	1.980E 0
3500.	1.514E -1	8.595E -1	1.762E 0	8500.	4.902E -3	9.951E -1	1.981E 0
3600.	1.423E -1	8.674E -1	1.777E 0	8600.	4.535E -3	9.955E -1	1.981E 0
3700.	1.336E -1	8.750E -1	1.791E 0	8700.	4.187E -3	9.958E -1	1.982E 0
3800.	1.253E -1	8.822E -1	1.804E 0	8800.	3.855E -3	9.962E -1	1.982E 0
3900.	1.175E -1	8.892E -1	1.816E 0	8900.	3.540E -3	9.965E -1	1.982E 0
4000.	1.100E -1	8.958E -1	1.828E 0	9000.	3.240E -3	9.968E -1	1.983E 0
4100.	1.030E -1	9.021E -1	1.838E 0	9100.	2.956E -3	9.970E -1	1.983E 0
4200.	9.636E -2	9.081E -1	1.848E 0	9200.	2.686E -3	9.973E -1	1.983E 0
4300.	9.009E -2	9.139E -1	1.858E 0	9300.	2.430E -3	9.976E -1	1.984E 0
4400.	8.417E -2	9.193E -1	1.866E 0	9400.	2.189E -3	9.978E -1	1.984E 0
4500.	7.860E -2	9.244E -1	1.875E 0	9500.	1.961E -3	9.980E -1	1.984E 0
4600.	7.337E -2	9.293E -1	1.882E 0	9600.	1.748E -3	9.983E -1	1.984E 0
4700.	6.846E -2	9.338E -1	1.889E 0	9700.	1.549E -3	9.985E -1	1.984E 0
4800.	6.385E -2	9.381E -1	1.896E 0	9800.	1.363E -3	9.986E -1	1.985E 0
4900.	5.953E -2	9.422E -1	1.902E 0	9900.	1.191E -3	9.988E -1	1.985E 0
5000.	5.549E -2	9.460E -1	1.908E 0	10000.	1.034E -3	9.990E -1	1.985E 0

THE COEFFICIENTS FOR THE POLYNOMIAL FIT ARE

3.3336E -1   -1.0516E -3   3.1934E -7   -8.6606E-11   9.8027E-15   -4.0047E-19

TABLE 3d.
CO LASER LINE TRANSMITTANCE FOR 30^{o}N LATITUDE, JULY. ABSORPTANCE DUE TO WATER VAPOR ONLY.

LASER LINE AT 1936.002

ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)	ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)
0.	1.633E 0	1.600E -1	0.000E 0				
100.	1.654E 0	1.913E -1	1.750E -1	5100.	6.675E -2	9.354E -1	2.497E 0
200.	1.501E 0	2.228E -1	3.333E -1	5200.	6.218E -2	9.397E -1	2.503E 0
300.	1.370E 0	2.540E -1	4.774E -1	5300.	5.792E -2	9.437E -1	2.509E 0
400.	1.257E 0	2.845E -1	6.092E -1	5400.	5.396E -2	9.475E -1	2.515E 0
500.	1.156E 0	3.141E -1	7.304E -1	5500.	5.026E -2	9.510E -1	2.520E 0
600.	1.071E 0	3.425E -1	8.422E -1	5600.	4.682E -2	9.543E -1	2.525E 0
700.	9.949E -1	3.698E -1	9.456E -1	5700.	4.362E -2	9.573E -1	2.530E 0
800.	9.259E -1	3.958E -1	1.042E 0	5800.	4.065E -2	9.602E -1	2.534E 0
900.	8.641E -1	4.206E -1	1.132E 0	5900.	3.789E -2	9.628E -1	2.538E 0
1000.	8.114E -1	4.442E -1	1.216E 0	6000.	3.532E -2	9.653E -1	2.541E 0
1100.	7.620E -1	4.667E -1	1.295E 0	6100.	3.293E -2	9.676E -1	2.545E 0
1200.	7.179E -1	4.882E -1	1.369E 0	6200.	3.072E -2	9.697E -1	2.548E 0
1300.	6.758E -1	5.088E -1	1.439E 0	6300.	2.866E -2	9.717E -1	2.551E 0
1400.	6.379E -1	5.284E -1	1.505E 0	6400.	2.675E -2	9.736E -1	2.554E 0
1500.	6.026E -1	5.474E -1	1.567E 0	6500.	2.497E -2	9.753E -1	2.556E 0
1600.	5.719E -1	5.654E -1	1.626E 0	6600.	2.332E -2	9.769E -1	2.559E 0
1700.	5.392E -1	5.828E -1	1.681E 0	6700.	2.179E -2	9.784E -1	2.561E 0
1800.	5.114E -1	5.994E -1	1.734E 0	6800.	2.036E -2	9.798E -1	2.563E 0
1900.	4.846E -1	6.159E -1	1.784E 0	6900.	1.903E -2	9.812E -1	2.565E 0
2000.	4.594E -1	6.317E -1	1.831E 0	7000.	1.779E -2	9.824E -1	2.567E 0
2100.	4.354E -1	6.470E -1	1.876E 0	7100.	1.664E -2	9.835E -1	2.569E 0
2200.	4.127E -1	6.619E -1	1.919E 0	7200.	1.556E -2	9.846E -1	2.570E 0
2300.	3.911E -1	6.763E -1	1.959E 0	7300.	1.455E -2	9.856E -1	2.572E 0
2400.	3.705E -1	6.904E -1	1.997E 0	7400.	1.361E -2	9.865E -1	2.573E 0
2500.	3.509E -1	7.041E -1	2.033E 0	7500.	1.273E -2	9.874E -1	2.575E 0
2600.	3.321E -1	7.174E -1	2.066E 0	7600.	1.190E -2	9.882E -1	2.576E 0
2700.	3.141E -1	7.304E -1	2.100E 0	7700.	1.112E -2	9.889E -1	2.577E 0
2800.	2.970E -1	7.431E -1	2.131E 0	7800.	1.039E -2	9.897E -1	2.578E 0
2900.	2.805E -1	7.554E -1	2.160E 0	7900.	9.700E -3	9.903E -1	2.579E 0
3000.	2.648E -1	7.673E -1	2.187E 0	8000.	9.050E -3	9.910E -1	2.580E 0
3100.	2.498E -1	7.789E -1	2.213E 0	8100.	8.436E -3	9.916E -1	2.581E 0
3200.	2.355E -1	7.902E -1	2.237E 0	8200.	7.856E -3	9.922E -1	2.582E 0
3300.	2.217E -1	8.011E -1	2.260E 0	8300.	7.305E -3	9.927E -1	2.583E 0
3400.	2.086E -1	8.117E -1	2.282E 0	8400.	6.783E -3	9.932E -1	2.583E 0
3500.	1.962E -1	8.219E -1	2.302E 0	8500.	6.288E -3	9.937E -1	2.584E 0
3600.	1.843E -1	8.317E -1	2.321E 0	8600.	5.817E -3	9.942E -1	2.584E 0
3700.	1.730E -1	8.412E -1	2.339E 0	8700.	5.369E -3	9.946E -1	2.585E 0
3800.	1.622E -1	8.502E -1	2.356E 0	8800.	4.944E -3	9.951E -1	2.586E 0
3900.	1.521E -1	8.589E -1	2.371E 0	8900.	4.539E -3	9.955E -1	2.586E 0
4000.	1.424E -1	8.673E -1	2.386E 0	9000.	4.154E -3	9.959E -1	2.586E 0
4100.	1.333E -1	8.752E -1	2.400E 0	9100.	3.789E -3	9.962E -1	2.587E 0
4200.	1.246E -1	8.828E -1	2.413E 0	9200.	3.442E -3	9.966E -1	2.587E 0
4300.	1.165E -1	8.900E -1	2.425E 0	9300.	3.115E -3	9.969E -1	2.588E 0
4400.	1.088E -1	8.969E -1	2.436E 0	9400.	2.805E -3	9.972E -1	2.588E 0
4500.	1.016E -1	9.034E -1	2.447E 0	9500.	2.513E -3	9.975E -1	2.588E 0
4600.	9.480E -2	9.096E -1	2.457E 0	9600.	2.240E -3	9.978E -1	2.588E 0
4700.	8.843E -2	9.154E -1	2.466E 0	9700.	1.984E -3	9.980E -1	2.589E 0
4800.	8.246E -2	9.208E -1	2.475E 0	9800.	1.746E -3	9.983E -1	2.589E 0
4900.	7.687E -2	9.260E -1	2.483E 0	9900.	1.526E -3	9.985E -1	2.589E 0
5000.	7.163E -2	9.309E -1	2.490E 0	10000.	1.324E -3	9.967E -1	2.589E 0

THE COEFFICIENTS FOR THE POLYNOMIAL FIT ARE

6.0589E -1 -1.0581E -3 3.2064E -7 -8.6818E-11 9.8202E-15 -4.0101E-19

TABLE 3e.

CO LASER LINE TRANSMITTANCE FOR 30°N LATITUDE, JULY. ABSORPTANCE DUE TO WATER VAPOR ONLY.

LASER LINE AT 1951.360

ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)	ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)
0.	1.963E 0	1.377E -1	0.000E 0				
100.	1.789E 0	1.671E -1	1.893E -1	5100.	7.177E -2	9.307E -1	2.700E 0
200.	1.624E 0	1.970E -1	3.606E -1	5200.	6.665E -2	9.353E -1	2.706E 0
300.	1.483E 0	2.270E -1	5.165E -1	5300.	6.225E -2	9.396E -1	2.713E 0
400.	1.360E 0	2.567E -1	6.591E -1	5400.	5.797E -2	9.437E -1	2.719E 0
500.	1.253E 0	2.856E -1	7.902E -1	5500.	5.399E -2	9.474E -1	2.725E 0
600.	1.159E 0	3.137E -1	9.112E -1	5600.	5.028E -2	9.510E -1	2.730E 0
700.	1.076E 0	3.406E -1	1.023E 0	5700.	4.683E -2	9.542E -1	2.735E 0
800.	1.003E 0	3.668E -1	1.128E 0	5800.	4.363E -2	9.573E -1	2.739E 0
900.	9.370E -1	3.916E -1	1.225E 0	5900.	4.065E -2	9.602E -1	2.743E 0
1000.	8.779E -1	4.157E -1	1.316E 0	6000.	3.788E -2	9.628E -1	2.747E 0
1100.	8.243E -1	4.385E -1	1.401E 0	6100.	3.531E -2	9.653E -1	2.751E 0
1200.	7.756E -1	4.604E -1	1.481E 0	6200.	3.292E -2	9.676E -1	2.754E 0
1300.	7.310E -1	4.814E -1	1.557E 0	6300.	3.071E -2	9.698E -1	2.758E 0
1400.	6.899E -1	5.016E -1	1.628E 0	6400.	2.865E -2	9.718E -1	2.761E 0
1500.	6.520E -1	5.210E -1	1.695E 0	6500.	2.673E -2	9.736E -1	2.763E 0
1600.	6.167E -1	5.397E -1	1.759E 0	6600.	2.496E -2	9.754E -1	2.766E 0
1700.	5.838E -1	5.578E -1	1.819E 0	6700.	2.331E -2	9.770E -1	2.768E 0
1800.	5.529E -1	5.753E -1	1.876E 0	6800.	2.177E -2	9.785E -1	2.771E 0
1900.	5.239E -1	5.922E -1	1.930E 0	6900.	2.034E -2	9.799E -1	2.773E 0
2000.	4.966E -1	6.086E -1	1.981E 0	7000.	1.901E -2	9.812E -1	2.775E 0
2100.	4.706E -1	6.246E -1	2.030E 0	7100.	1.777E -2	9.824E -1	2.777E 0
2200.	4.460E -1	6.402E -1	2.076E 0	7200.	1.661E -2	9.835E -1	2.778E 0
2300.	4.226E -1	6.553E -1	2.119E 0	7300.	1.552E -2	9.846E -1	2.780E 0
2400.	4.003E -1	6.701E -1	2.160E 0	7400.	1.451E -2	9.856E -1	2.781E 0
2500.	3.791E -1	6.845E -1	2.199E 0	7500.	1.356E -2	9.865E -1	2.783E 0
2600.	3.587E -1	6.986E -1	2.236E 0	7600.	1.268E -2	9.874E -1	2.784E 0
2700.	3.393E -1	7.123E -1	2.271E 0	7700.	1.184E -2	9.882E -1	2.785E 0
2800.	3.207E -1	7.256E -1	2.305E 0	7800.	1.106E -2	9.890E -1	2.787E 0
2900.	3.029E -1	7.386E -1	2.336E 0	7900.	1.032E -2	9.897E -1	2.788E 0
3000.	2.859E -1	7.513E -1	2.365E 0	8000.	9.623E -3	9.904E -1	2.789E 0
3100.	2.697E -1	7.636E -1	2.393E 0	8100.	8.965E -3	9.911E -1	2.790E 0
3200.	2.541E -1	7.756E -1	2.419E 0	8200.	8.344E -3	9.917E -1	2.790E 0
3300.	2.393E -1	7.872E -1	2.444E 0	8300.	7.755E -3	9.923E -1	2.791E 0
3400.	2.251E -1	7.984E -1	2.467E 0	8400.	7.197E -3	9.928E -1	2.792E 0
3500.	2.116E -1	8.093E -1	2.489E 0	8500.	6.668E -3	9.934E -1	2.793E 0
3600.	1.984E -1	8.197E -1	2.510E 0	8600.	6.165E -3	9.939E -1	2.793E 0
3700.	1.866E -1	8.296E -1	2.529E 0	8700.	5.688E -3	9.943E -1	2.794E 0
3800.	1.749E -1	8.395E -1	2.547E 0	8800.	5.234E -3	9.948E -1	2.794E 0
3900.	1.639E -1	8.486E -1	2.564E 0	8900.	4.803E -3	9.952E -1	2.795E 0
4000.	1.535E -1	8.577E -1	2.580E 0	9000.	4.393E -3	9.956E -1	2.795E 0
4100.	1.436E -1	8.662E -1	2.595E 0	9100.	4.005E -3	9.960E -1	2.796E 0
4200.	1.343E -1	8.743E -1	2.609E 0	9200.	3.636E -3	9.964E -1	2.796E 0
4300.	1.255E -1	8.821E -1	2.622E 0	9300.	3.286E -3	9.967E -1	2.797E 0
4400.	1.172E -1	8.894E -1	2.634E 0	9400.	2.959E -3	9.970E -1	2.797E 0
4500.	1.094E -1	8.964E -1	2.646E 0	9500.	2.650E -3	9.974E -1	2.797E 0
4600.	1.021E -1	9.030E -1	2.656E 0	9600.	2.360E -3	9.976E -1	2.797E 0
4700.	9.519E -2	9.092E -1	2.666E 0	9700.	2.090E -3	9.979E -1	2.796E 0
4800.	8.874E -2	9.151E -1	2.675E 0	9800.	1.838E -3	9.982E -1	2.796E 0
4900.	8.270E -2	9.206E -1	2.684E 0	9900.	1.606E -3	9.984E -1	2.798E 0
5000.	7.705E -2	9.258E -1	2.692E 0	10000.	1.393E -3	9.986E -1	2.796E 0

THE COEFFICIENTS FOR THE POLYNOMIAL FIT ARE

6.6453E -1 -1.0574E -3 3.1963E -7 -8.6634E-11 9.7960E-15 -3.9996E-19

TABLE 3f.

CO LASER LINE TRANSMITTANCE FOR 30^{o}N LATITUDE, JULY. ABSORPTANCE DUE TO WATER VAPOR ONLY.

NOT REPRODUCIBLE

LASER LINE AT 1900.043

ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)	ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)
0.	2.442E 0	8.700E -2	0.000E 0				
100.	2.207E 0	1.100E -1	2.333E -1	5100.	9.526E -2	9.091E -1	3.394E 0
200.	2.007E 0	1.344E -1	4.448E -1	5200.	8.888E -2	9.150E -1	3.403E 0
300.	1.835E 0	1.597E -1	6.375E -1	5300.	8.292E -2	9.204E -1	3.412E 0
400.	1.685E 0	1.854E -1	8.140E -1	5400.	7.736E -2	9.256E -1	3.420E 0
500.	1.55[illegible]E 0	2.111E -1	9.766E -1	5500.	7.217E -2	9.304E -1	3.427E 0
600.	1.441E 0	2.367E -1	1.127E 0	5600.	6.734E -2	9.349E -1	3.434E 0
700.	1.340E 0	2.618E -1	1.266E 0	5700.	6.284E -2	9.391E -1	3.441E 0
800.	1.250E 0	2.864E -1	1.396E 0	5800.	5.865E -2	9.430E -1	3.447E 0
900.	1.175E 0	3.103E -1	1.518E 0	5900.	5.476E -2	9.467E -1	3.453E 0
1000.	1.0[illegible]E 0	[illegible] -1	1.631E 0	6000.	5.113E -2	9.502E -1	3.45[illegible]E 0
1100.	1.032E 0	3.562E -1	1.738E 0	6100.	4.776E -2	9.534E -1	3.463E 0
1200.	9.727E -1	3.791E -1	1.839E 0	6200.	4.462E -2	9.564E -1	3.467E 0
1300.	9.161E -1	3.998E -1	1.935E 0	6300.	4.171E -2	9.592E -1	3.47[illegible]E 0
1400.	8.675E -1	4.199E -1	2.023E 0	6400.	3.899E -2	9.618E -1	3.476E 0
1500.	8.213E -1	4.399E -1	2.107E 0	6500.	3.647E -2	9.642E -1	3.480E 0
1600.	7.779E -1	4.594E -1	2.188E 0	6600.	3.412E -2	9.665E -1	3.483E 0
1700.	7.375E -1	4.785E -1	2.264E 0	6700.	3.194E -2	9.686E -1	3.486E 0
1800.	6.99[illegible]E -1	4.966E -1	2.336E 0	6800.	2.990E -2	9.705E -1	3.490E 0
1900.	6.637E -1	5.149E -1	2.404E 0	6900.	2.800E -2	9.724E -1	3.492E 0
2000.	6.299E -1	5.326E -1	2.469E 0	7000.	2.623E -2	9.741E -1	3.495E 0
2100.	5.978E -1	5.500E -1	2.530E 0	7100.	2.458E -2	9.757E -1	3.498E 0
2200.	5.674E -1	5.670E -1	2.569E 0	7200.	2.303E -2	9.772E -1	3.500E 0
2300.	[illegible] -1	5.837E -1	2.644E 0	7300.	2.158E -2	9.786E -1	3.502E 0
2400.	5.106E -1	6.001E -1	2.697E 0	7400.	2.023E -2	9.800E -1	3.504E 0
2500.	4.842E -1	6.162E -1	2.747E 0	7500.	1.895E -2	9.812E -1	3.506E 0
2600.	4.588E -1	[illegible] -1	2.794E 0	7600.	1.776E -2	9.824E -1	3.508E 0
2700.	4.348E -1	6.475E -1	2.839E 0	7700.	1.663E -2	9.835E -1	3.510E 0
2800.	4.113E -1	6.626E -1	2.881E 0	7600.	1.557E -2	9.845E -1	3.512E 0
2900.	3.890E -1	6.777E -1	2.921E 0	7900.	1.457E -2	9.855E -1	3.513E 0
3000.	3.677E -1	6.923E -1	2.959E 0	8000.	1.362E -2	9.865E -1	3.515E 0
3100.	3.475E -1	7.066E -1	2.995E 0	8100.	1.273E -2	9.874E -1	3.516E 0
3200.	3.277E -1	7.206E -1	3.029E 0	8200.	1.188E -2	9.882E -1	3.517E 0
3300.	3.096E -1	7.342E -1	3.061E 0	8300.	1.107E -2	9.890E -1	3.518E 0
3400.	2.911E -1	7.474E -1	3.091E 0	8400.	1.030E -2	9.898E -1	3.519E 0
3500.	2.740E -1	7.603E -1	3.119E 0	8500.	9.570E -3	9.905E -1	3.520E 0
3600.	2.578E -1	7.728E -1	3.146E 0	0600.	8.873E -3	9.912E -1	3.521E 0
3700.	2.423E -1	7.849E -1	3.171E 0	8700.	8.209E -3	9.916E -1	3.522E 0
3800.	2.275E -1	7.965E -1	3.194E 0	8800.	7.575E -3	9.925E -1	3.523E 0
3900.	2.135E -1	8.070E -1	3.216E 0	8900.	6.970E -3	9.931E -1	3.524E 0
4000.	2.002E -1	8.186E -1	3.237E 0	9000.	6.394E -3	9.936E -1	3.524E 0
4100.	1.876E -1	8.290E -1	3.257E 0	9100.	5.845E -3	9.942E -1	3.525E 0
4200.	1.757E -1	8.389E -1	3.275E 0	9200.	5.322E -3	9.947E -1	3.525E 0
4300.	1.644E -1	8.48[illegible]E -1	3.292E 0	9300.	4.826E -3	9.952E -1	3.526E 0
4400.	1.538E -1	8.575E -1	3.308E 0	9400.	4.355E -3	9.957E -1	3.526E 0
4500.	1.439E -1	8.661E -1	3.323E 0	9500.	3.911E -3	9.961E -1	3.527E 0
4600.	1.343E -1	8.743E -1	3.337E 0	9600.	3.493E -3	9.965E -1	3.527E 0
4700.	1.255E -1	8.821E -1	3.350E 0	9700.	3.101E -3	9.969E -1	3.526E 0
4800.	1.172E -1	8.894E -1	3.362E 0	9800.	2.735E -3	9.973E -1	3.528E 0
4900.	1.094E -1	8.964E -1	3.373E 0	9900.	2.395E -3	9.976E -1	3.528E 0
5000.	1.021E -1	9.029E -1	3.364E 0	10000.	2.082E -3	9.979E -1	3.528E 0

THE COEFFICIENTS FOR THE POLYNOMIAL FIT ARE

6.9277E -1 -1.0416E -3 3.1951E -7 -8.6813E-11 9.8500E-15 -4.0289E-19

TABLE 3g.
CO LASER LINE TRANSMITTANCE FOR 30^{O}N LATITUDE, JULY. ABSORPTANCE DUE TO WATER VAPOR ONLY.

LASER LINE AT 1970.159

ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)	ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)
0.	3.153E 0	4.272E -2	0.000E 0				
100.	2.839E 0	5.847E -2	3.008E -1	5100.	1.005E -1	9.044E -1	4.161E 0
200.	2.572E 0	7.640E -2	5.723E -1	5200.	9.325E -2	9.110E -1	4.171E 0
300.	2.342E 0	9.612E -2	8.129E -1	5300.	8.655E -2	9.171E -1	4.180E 0
400.	2.144E 0	1.172E -1	1.044E 0	5400.	8.032E -2	9.228E -1	4.188E 0
500.	1.971E 0	1.394E -1	1.250E 0	5500.	7.454E -2	9.282E -1	4.196E 0
600.	1.819E 0	1.622E -1	1.440E 0	5600.	6.917E -2	9.332E -1	4.203E 0
700.	1.685E 0	1.854E -1	1.616E 0	5700.	6.419E -2	9.378E -1	4.210E 0
800.	1.567E 0	2.088E -1	1.779E 0	5800.	5.958E -2	9.422E -1	4.216E 0
900.	1.461E 0	2.321E -1	1.931E 0	5900.	5.531E -2	9.462E -1	4.222E 0
1000.	1.365E 0	2.553E -1	2.073E 0	6000.	5.135E -2	9.499E -1	4.227E 0
1100.	1.279E 0	2.783E -1	2.205E 0	6100.	4.768E -2	9.534E -1	4.232E 0
1200.	1.201E 0	3.010E -1	2.330E 0	6200.	4.429E -2	9.567E -1	4.237E 0
1300.	1.129E 0	3.233E -1	2.446E 0	6300.	4.114E -2	9.597E -1	4.241E 0
1400.	1.063E 0	3.453E -1	2.556E 0	6400.	3.823E -2	9.625E -1	4.245E 0
1500.	1.003E 0	3.669E -1	2.660E 0	6500.	3.554E -2	9.651E -1	4.249E 0
1600.	9.462E -1	3.882E -1	2.758E 0	6600.	3.304E -2	9.675E -1	4.252E 0
1700.	8.937E -1	4.091E -1	2.850E 0	6700.	3.072E -2	9.697E -1	4.255E 0
1800.	8.446E -1	4.297E -1	2.937E 0	6800.	2.856E -2	9.718E -1	4.258E 0
1900.	7.984E -1	4.500E -1	3.019E 0	6900.	2.659E -2	9.738E -1	4.261E 0
2000.	7.550E -1	4.700E -1	3.097E 0	7000.	2.474E -2	9.756E -1	4.264E 0
2100.	7.139E -1	4.897E -1	3.171E 0	7100.	2.303E -2	9.772E -1	4.266E 0
2200.	6.751E -1	5.091E -1	3.240E 0	7200.	2.143E -2	9.788E -1	4.268E 0
2300.	6.382E -1	5.283E -1	3.306E 0	7300.	1.995E -2	9.802E -1	4.270E 0
2400.	6.031E -1	5.471E -1	3.368E 0	7400.	1.857E -2	9.816E -1	4.272E 0
2500.	5.697E -1	5.657E -1	3.427E 0	7500.	1.728E -2	9.829E -1	4.274E 0
2600.	5.379E -1	5.840E -1	3.483E 0	7600.	1.608E -2	9.841E -1	4.276E 0
2700.	5.075E -1	6.020E -1	3.535E 0	7700.	1.495E -2	9.852E -1	4.277E 0
2800.	4.786E -1	6.197E -1	3.585E 0	7800.	1.390E -2	9.862E -1	4.279E 0
2900.	4.510E -1	6.370E -1	3.631E 0	7900.	1.292E -2	9.872E -1	4.280E 0
3000.	4.246E -1	6.540E -1	3.675E 0	8000.	1.199E -2	9.881E -1	4.281E 0
3100.	3.995E -1	6.707E -1	3.716E 0	8100.	1.112E -2	9.889E -1	4.282E 0
3200.	3.755E -1	6.869E -1	3.755E 0	8200.	1.031E -2	9.897E -1	4.283E 0
3300.	3.527E -1	7.028E -1	3.792E 0	8300.	9.537E -3	9.905E -1	4.284E 0
3400.	3.310E -1	7.182E -1	3.826E 0	8400.	8.813E -3	9.912E -1	4.285E 0
3500.	3.104E -1	7.332E -1	3.858E 0	8500.	8.130E -3	9.919E -1	4.286E 0
3600.	2.908E -1	7.477E -1	3.888E 0	8600.	7.485E -3	9.925E -1	4.287E 0
3700.	2.722E -1	7.617E -1	3.917E 0	8700.	6.876E -3	9.931E -1	4.288E 0
3800.	2.545E -1	7.753E -1	3.943E 0	8800.	6.301E -3	9.937E -1	4.288E 0
3900.	2.379E -1	7.883E -1	3.968E 0	8900.	5.758E -3	9.943E -1	4.289E 0
4000.	2.221E -1	8.008E -1	3.991E 0	9000.	5.246E -3	9.948E -1	4.290E 0
4100.	2.072E -1	8.128E -1	4.012E 0	9100.	4.763E -3	9.952E -1	4.290E 0
4200.	1.932E -1	8.243E -1	4.032E 0	9200.	4.309E -3	9.957E -1	4.291E 0
4300.	1.800E -1	8.352E -1	4.051E 0	9300.	3.882E -3	9.961E -1	4.291E 0
4400.	1.677E -1	8.456E -1	4.069E 0	9400.	3.481E -3	9.965E -1	4.291E 0
4500.	1.560E -1	8.555E -1	4.085E 0	9500.	3.107E -3	9.969E -1	4.292E 0
4600.	1.451E -1	8.649E -1	4.100E 0	9600.	2.758E -3	9.972E -1	4.292E 0
4700.	1.349E -1	8.738E -1	4.114E 0	9700.	2.434E -3	9.976E -1	4.292E 0
4800.	1.254E -1	8.821E -1	4.127E 0	9800.	2.134E -3	9.979E -1	4.292E 0
4900.	1.165E -1	8.900E -1	4.139E 0	9900.	1.859E -3	9.981E -1	4.293E 0
5000.	1.082E -1	8.975E -1	4.150E 0	10000.	1.608E -3	9.984E -1	4.293E 0

THE COEFFICIENTS FOR THE POLYNOMIAL FIT ARE

1.1484E 0 -1.0793E -3 3.1927E -7 -8.6319E-11 9.7030E-15 -3.9427E-19

TABLE 3h.
CO LASER LINE TRANSMITTANCE FOR 30°N LATITUDE, JULY. ABSORPTANCE DUE TO WATER VAPOR ONLY.

LASER LINE AT 1927.282

ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)	ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)
0.	3.076E 0	4.605E -2	0.000E 0				
100.	2.778E 0	6.215E -2	2.939E -1	5100.	1.128E -1	8.933E -1	4.202E 0
200.	2.522E 0	8.[illegible]E -2	5.599E -1	5200.	1.051E -1	9.002E -1	4.213E 0
300.	2.303E 0	10.[illegible]E -2	8.020E -1	5300.	9.791E -2	9.067E -1	4.223E 0
400.	2.112E 0	1.2[illegible]9E -1	1.024E 0	5400.	9.121E -2	9.128E -1	4.233E 0
500.	1.947E 0	1.42[illegible]E -1	1.227E 0	5500.	8.497E -2	9.185E -1	4.242E 0
600.	1.801E 0	1.651E -1	1.415E 0	5600.	7.917E -2	9.239E -1	4.250E 0
700.	1.674E 0	1.877E -1	1.589E 0	5700.	7.377E -2	9.289E -1	4.257E 0
800.	1.559E 0	2.104E -1	1.751E 0	5800.	6.874E -2	9.336E -1	4.265E 0
900.	1.457E 0	2.33[illegible]E -1	1.902E 0	5900.	6.408E -2	9.379E -1	4.271E 0
1000.	1.369E 0	2.[illegible]E -1	2.044E 0	6000.	5.974E -2	9.420E -1	4.277E 0
1100.	1.282E 0	2.77[illegible]E -1	2.177E 0	6100.	5.571E -2	9.458E -1	4.283E 0
1200.	1.207E 0	2.99[illegible]E -1	2.301E 0	6200.	5.197E -2	9.494E -1	4.289E 0
1300.	1.137E 0	3.207E -1	2.419E 0	6300.	4.849E -2	9.527E -1	4.294E 0
1400.	1.074E 0	3.417E -1	2.530E 0	6400.	4.526E -2	9.558E -1	4.298E 0
1500.	1.015E 0	3.624E -1	2.634E 0	6500.	4.226E -2	9.586E -1	4.303E 0
1600.	9.602E -1	3.828E -1	2.733E 0	6600.	3.947E -2	9.613E -1	4.307E 0
1700.	9.092E -1	4.029E -1	2.827E 0	6700.	3.687E -2	9.638E -1	4.311E 0
1800.	8.613E -1	4.226E -1	2.916E 0	6800.	3.446E -2	9.661E -1	4.314E 0
1900.	8.163E -1	4.421E -1	3.000E 0	6900.	3.221E -2	9.683E -1	4.316E 0
2000.	7.738E -1	4.612E -1	3.080E 0	7000.	3.012E -2	9.703E -1	4.321E 0
2100.	7.336E -1	4.802E -1	3.155E 0	7100.	2.816E -2	9.722E -1	4.324E 0
2200.	6.954E -1	4.989E -1	3.227E 0	7200.	2.634E -2	9.740E -1	4.326E 0
2300.	6.591E -1	5.173E -1	3.295E 0	7300.	2.464E -2	9.757E -1	4.329E 0
2400.	6.245E -1	5.356E -1	3.359E 0	7400.	2.304E -2	9.772E -1	4.331E 0
2500.	5.914E -1	5.536E -1	3.420E 0	7500.	2.155E -2	9.787E -1	4.334E 0
2600.	5.598E -1	5.714E -1	3.476E 0	7600.	2.015E -2	9.801E -1	4.336E 0
2700.	5.296E -1	5.888E -1	3.532E 0	7700.	1.885E -2	9.813E -1	4.338E 0
2800.	5.[illegible] -1	6.061E -1	3.584E 0	7800.	1.766E -2	9.826E -1	4.339E 0
2900.	4.731E -1	6.231E -1	3.635E 0	7900.	1.643E -2	9.837E -1	4.341E 0
3000.	4.466E -1	6.398E -1	3.679E 0	8000.	1.535E -2	9.848E -1	4.343E 0
3100.	4.214E -1	6.562E -1	3.722E 0	8100.	1.429E -2	9.858E -1	4.344E 0
3200.	3.972E -1	6.722E -1	3.763E 0	8200.	1.331E -2	9.868E -1	4.346E 0
3300.	3.741E -1	6.879E -1	3.802E 0	8300.	1.238E -2	9.877E -1	4.347E 0
3400.	3.520E -1	7.033E -1	3.839E 0	8400.	1.149E -2	9.886E -1	4.348E 0
3500.	3.310E -1	7.182E -1	3.873E 0	8500.	1.065E -2	9.894E -1	4.349E 0
3600.	3.110E -1	7.327E -1	3.905E 0	8600.	9.856E -3	9.902E -1	4.350E 0
3700.	2.919E -1	7.468E -1	3.935E 0	8700.	9.098E -3	9.909E -1	4.351E 0
3800.	2.738E -1	7.605E -1	3.964E 0	8800.	8.377E -3	9.917E -1	4.352E 0
3900.	2.567E -1	7.736E -1	3.990E 0	8900.	7.651E -3	9.923E -1	4.353E 0
4000.	2.404E -1	7.863E -1	4.015E 0	9000.	7.039E -3	9.930E -1	4.354E 0
4100.	2.250E -1	7.985E -1	4.038E 0	9100.	6.420E -3	9.936E -1	4.354E 0
4200.	2.104E -1	8.102E -1	4.060E 0	9200.	5.833E -3	9.942E -1	4.355E 0
4300.	1.967E -1	8.214E -1	4.081E 0	9300.	5.278E -3	9.947E -1	4.355E 0
4400.	1.838E -1	8.321E -1	4.100E 0	9400.	4.753E -3	9.953E -1	4.356E 0
4500.	1.716E -1	8.423E -1	4.118E 0	9500.	4.259E -3	9.958E -1	4.356E 0
4600.	1.601E -1	8.520E -1	4.134E 0	9600.	3.795E -3	9.962E -1	4.357E 0
4700.	1.494E -1	8.612E -1	4.150E 0	9700.	3.362E -3	9.966E -1	4.357E 0
4800.	1.394E -1	8.700E -1	4.164E 0	9800.	2.959E -3	9.970E -1	4.357E 0
4900.	1.299E -1	8.782E -1	4.176E 0	9900.	2.586E -3	9.974E -1	4.358E 0
5000.	1.211E -1	8.860E -1	4.190E 0	10000.	2.243E -3	9.978E -1	4.358E 0

THE COEFFICIENTS FOR THE POLYNOMIAL FIT ARE

1.1243E 0 -1.0560E -3 3.2929E -7 --8.6764E-11 9.8165E-15 -4.0094E-19

NOT REPRODUCIBLE

TABLE 3i.
CO LASER LINE TRANSMITTANCE FOR 30^{o}N LATITUDE, JULY. ABSORPTANCE DUE TO WATER VAPOR ONLY.

LASER LINE AT 1986.918

ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)	ALTITUDE METER	EXT. COEF. 1/KM	1KM TRANS.	OPT. THICK. (0-H)
0.	3.450E 0	3.174E -2	0.000E 0				
100.	3.109E 0	4.464E -2	3.292E -1	5100.	1.168E -1	8.897E -1	4.612E 0
200.	2.818E 0	5.970E -2	6.267E -1	5200.	1.087E -1	8.970E -1	4.623E 0
300.	2.569E 0	7.663E -2	8.970E -1	5300.	1.010E -1	9.039E -1	4.634E 0
400.	2.353E 0	9.510E -2	1.144E 0	5400.	9.393E -2	9.103E -1	4.643E 0
500.	2.164E 0	1.148E -1	1.370E 0	5500.	8.734E -2	9.164E -1	4.652E 0
600.	2.000E 0	1.353E -1	1.579E 0	5600.	8.120E -2	9.220E -1	4.661E 0
700.	1.859E 0	1.565E -1	1.773E 0	5700.	7.551E -2	9.273E -1	4.669E 0
800.	1.728E 0	1.751E -1	1.952E 0	5800.	7.022E -2	9.322E -1	4.676E 0
900.	1.610E 0	1.999E -1	2.119E 0	5900.	6.531E -2	9.368E -1	4.683E 0
1000.	1.506E 0	2.217E -1	2.276E 0	6000.	6.076E -2	9.411E -1	4.689E 0
1100.	1.413E 0	2.435E -1	2.422E 0	6100.	5.653E -2	9.450E -1	4.695E 0
1200.	1.327E 0	2.652E -1	2.559E 0	6200.	5.261E -2	9.487E -1	4.700E 0
1300.	1.249E 0	2.867E -1	2.689E 0	6300.	4.898E -2	9.522E -1	4.706E 0
1400.	1.178E 0	3.080E -1	2.810E 0	6400.	4.561E -2	9.554E -1	4.710E 0
1500.	1.111E 0	3.291E -1	2.925E 0	6500.	4.248E -2	9.584E -1	4.715E 0
1600.	1.050E 0	3.499E -1	3.033E 0	6600.	3.958E -2	9.612E -1	4.719E 0
1700.	9.927E -1	3.706E -1	3.136E 0	6700.	3.689E -2	9.638E -1	4.723E 0
1800.	9.391E -1	3.910E -1	3.232E 0	6800.	3.439E -2	9.662E -1	4.726E 0
1900.	8.887E -1	4.112E -1	3.324E 0	6900.	3.206E -2	9.684E -1	4.730E 0
2000.	8.412E -1	4.312E -1	3.411E 0	7000.	2.990E -2	9.705E -1	4.733E 0
2100.	7.963E -1	4.510E -1	3.493E 0	7100.	2.789E -2	9.725E -1	4.736E 0
2200.	7.538E -1	4.706E -1	3.571E 0	7200.	2.601E -2	9.743E -1	4.738E 0
2300.	7.134E -1	4.900E -1	3.644E 0	7300.	2.427E -2	9.760E -1	4.741E 0
2400.	6.749E -1	5.092E -1	3.714E 0	7400.	2.263E -2	9.776E -1	4.743E 0
2500.	6.383E -1	5.282E -1	3.780E 0	7500.	2.111E -2	9.791E -1	4.745E 0
2600.	6.033E -1	5.470E -1	3.842E 0	7600.	1.968E -2	9.805E -1	4.747E 0
2700.	5.699E -1	5.656E -1	3.901E 0	7700.	1.835E -2	9.818E -1	4.749E 0
2800.	5.381E -1	5.839E -1	3.956E 0	7800.	1.709E -2	9.831E -1	4.751E 0
2900.	5.076E -1	6.019E -1	4.009E 0	7900.	1.591E -2	9.842E -1	4.753E 0
3000.	4.786E -1	6.197E -1	4.058E 0	8000.	1.480E -2	9.853E -1	4.754E 0
3100.	4.508E -1	6.371E -1	4.105E 0	8100.	1.376E -2	9.863E -1	4.756E 0
3200.	4.243E -1	6.542E -1	4.148E 0	8200.	1.278E -2	9.873E -1	4.757E 0
3300.	3.990E -1	6.710E -1	4.190E 0	8300.	1.185E -2	9.882E -1	4.758E 0
3400.	3.750E -1	6.873E -1	4.229E 0	8400.	1.097E -2	9.891E -1	4.759E 0
3500.	3.521E -1	7.032E -1	4.265E 0	8500.	1.014E -2	9.899E -1	4.760E 0
3600.	3.303E -1	7.187E -1	4.299E 0	8600.	9.349E -3	9.907E -1	4.761E 0
3700.	3.096E -1	7.336E -1	4.331E 0	8700.	8.604E -3	9.914E -1	4.762E 0
3800.	2.899E -1	7.483E -1	4.361E 0	8800.	7.898E -3	9.921E -1	4.763E 0
3900.	2.713E -1	7.624E -1	4.390E 0	8900.	7.230E -3	9.928E -1	4.764E 0
4000.	2.537E -1	7.759E -1	4.416E 0	9000.	6.597E -3	9.934E -1	4.765E 0
4100.	2.371E -1	7.889E -1	4.440E 0	9100.	5.999E -3	9.940E -1	4.765E 0
4200.	2.214E -1	8.014E -1	4.463E 0	9200.	5.434E -3	9.946E -1	4.766E 0
4300.	2.066E -1	8.133E -1	4.485E 0	9300.	4.902E -3	9.951E -1	4.766E 0
4400.	1.927E -1	8.247E -1	4.505E 0	9400.	4.401E -3	9.956E -1	4.767E 0
4500.	1.796E -1	8.356E -1	4.524E 0	9500.	3.932E -3	9.961E -1	4.767E 0
4600.	1.674E -1	8.459E -1	4.541E 0	9600.	3.494E -3	9.965E -1	4.768E 0
4700.	1.559E -1	8.557E -1	4.557E 0	9700.	3.086E -3	9.969E -1	4.768E 0
4800.	1.451E -1	8.649E -1	4.572E 0	9800.	2.709E -3	9.973E -1	4.768E 0
4900.	1.350E -1	8.737E -1	4.586E 0	9900.	2.361E -3	9.976E -1	4.769E 0
5000.	1.256E -1	8.820E -1	4.600E 0	10000.	2.043E -3	9.980E -1	4.769E 0

THE COEFFICIENTS FOR THE POLYNOMIAL FIT ARE

1.2384E 0 -1.0719E -3 3.2032E -7 -8.6512E-11 9.7515E-15 -3.9748E-19
SEOJ

TIME 00HRS 04MIN 19.309SEC

TABLE 3j.
CL LASER LINE TRANSMITTANCE FOR 30^{O}N LATITUDE, JULY. ABSORPTANCE DUE TO WATER VAPOR ONLY.

NOT REPRODUCIBLE

Selection of the CO Laser Emission Lines

Determination of the laser lines to be used in the experimental studies is complex as it is not possible to find a laser line that is "best" for all atmospheric models, or even all conditions of temperature and pressure in a single model. Even using a single absorber in the atmospheric model a "best" line can not be found as illustrated from the computed transmittances described in Chapter II.

An example of this effect is illustrated in Table 1b. At 1:00 PM on January 4, 1971 the laser lines are ordered by decreasing transmittance through the atmosphere. The temperature was 30°F and the relative humidity was 91%. At 4:00 AM on the same day the temperature was 25°F and the relative humidity was 84%. The seventh and eighth laser lines in this list should now be interchanged so that the list of laser lines are ordered by decreasing transmittance. With greater extremes of temperature and relative humidity variations, this effect is more pronounced.

The reason no "best" line can be found is that the shape of each line's absorption coefficient is a function of the temperature and pressure, and does not depend solely upon the concentration of the particular absorber. For most applications a "good" laser line for laboratory measurement should have the following characteristics;

1) Be relatively far from any strong absorption line of molecules occurring in the atmosphere.

2) Not be too close to another laser line so that determination of the actual frequency would be difficult.

3) To test the accuracy of computations one or more laser lines which are close to an absorption line peak should be selected.

Appreciable absorptance (<10%) must occur so that accurate transmittance measurements can be made. The absorptance, within certain ranges, can be varied by changing the concentration of the absorber or the optical path length. The amount of water vapor in the path is limited as condensation occurs on the mirrors for high relative humidities and the maximum obtainable optical path is about 1 kilometer.

The most stringent test of the accuracy of the atmospheric model calculations is for laser lines separated from the center of the absorption line by about one half the width of the absorption line. Here the transmittance is rapidly changing with frequency and uncertainties in the parameters of the absorbing molecules produce the greatest error in the calculations.

Obviously not all of these requirements can be simultaneously achieved with a single line. For this reason ten lines have been tentatively selected that have the lowest absorption coefficient in a one kilometer horizontal path at sea level for the midlatitude Winter atmospheric model described by McClatchey et al.[7]

The 10 lines are listed in Table 4 with the identification of each line, and the calculated absorption coefficient and transmittance for a one kilometer horizontal path at sea level for the above model atmosphere. Only water vapor was considered to attenuate the radiant flux.

Additional laser lines will be measured provided these lines do not sufficiently meet all requirements listed above.

TABLE 4

TRANSMITTANCE OF SELECTED LASER LINES THROUGH
30°N LATITUDE, JULY MODEL ATMOSPHERE

FREQUENCY (cm^{-1})	BAND	LINE	ABSORPTION COEFFICIENT Km^{-1}	TRANSMITTANCE 1 Km
1978.609	5-4	P15	0.0412	0.960
1974.357	5-4	P16	0.0627	0.939
1982.766	5-4	P14	0.0655	0.937
1952.888	6-5	P15	0.147	0.863
1936.002	6-5	P19	0.172	0.842
1931.380	7-6	P14	0.206	0.814
1900.044	9-8	P9	0.259	0.772
1970.159	5-4	P17	0.275	0.760
1927.283	7-6	P15	0.337	0.714
1986.918	5-4	P13	0.364	0.695

Molecular Absorbers in the Atmosphere

The main molecular absorber in the atmosphere of the CO laser radiant flux is water vapor and the first experiments will use mixtures of water vapor and nitrogen. Other absorbers are CO_2, O_3, CH_4, CO, NO, and N_2O. Data on the molecular parameters of these molecules is being collected so that the influence of each can be calculated with the previously described computer programs. If from these calculations, it is found that any of these absorbers significantly decreases the transmittance over a one kilometer path, they will be included in the experimental program.

Experimental Apparatus

A conceptual design of the experiment is shown in Fig. 4. A description of the component is listed here.

CO Laser

The CO laser shown in Fig. 5 is to be loaned to us by Charles Freed of Lincoln Laboratory, Massachusetts Institute of Technology and is expected to be delivered in mid November. Over 60 CO lines in the spectral region 1800 to 1985 cm^{-1}, shown in Fig. 6, have been observed in a similar laser.[8] The refrigerator and power supplies for the laser have been ordered and delivery is partially completed. A filling station has been designed for refilling the laser.

The laser will emit individual emission lines as determined by the position of the grating located at one end of the laser cavity. The maximum power output of a single line is about 300 mw.

Multiple Traversal Absorption Cell

The multiple traversal absorption cell designed and built by Long[9] and modified by McCoy[5] can have optical path lengths of more than 1000 meters through the use of a three mirror White type optical system shown in Fig. 7. The actual size of the cell is two feet in diameter and fifty three feet in length. The three concave, aluminum coated mirrors each have a fifty foot radius of curvature and are placed exactly fifty feet apart. The two closely spaced mirrors, A and B, are halves of a twenty inch diameter spherical mirror. The third mirror, C, is a twelve inch diameter spherical mirror. Tilting the two halves of the split mirror changes the number of traversals radiant flux travels in passing through the cell.

The external optics are arranged such that the incoming laser beam is brought to a focus just as it passes the front surface of the twelve inch mirror and diverges to fill about one half of one of the ten inch mirrors. The beam is reflected and an image formed at the surface of the twelve inch mirror where the beam is re-reflected to the other ten inch mirror. After being reflected off this mirror the beam either exits or is reflected through the absorption cell again depending on the tilt of the two ten inch mirrors. The total number of traversals, N, through the cell can be determined from the number of images, n, formed on the twelve inch mirror, i.e.,

$$N = 2n + 2. \tag{9}$$

The windows of the cell are polished calcium flouride, as this material is not hygroscopic and has a high transmittance at 5 μm.

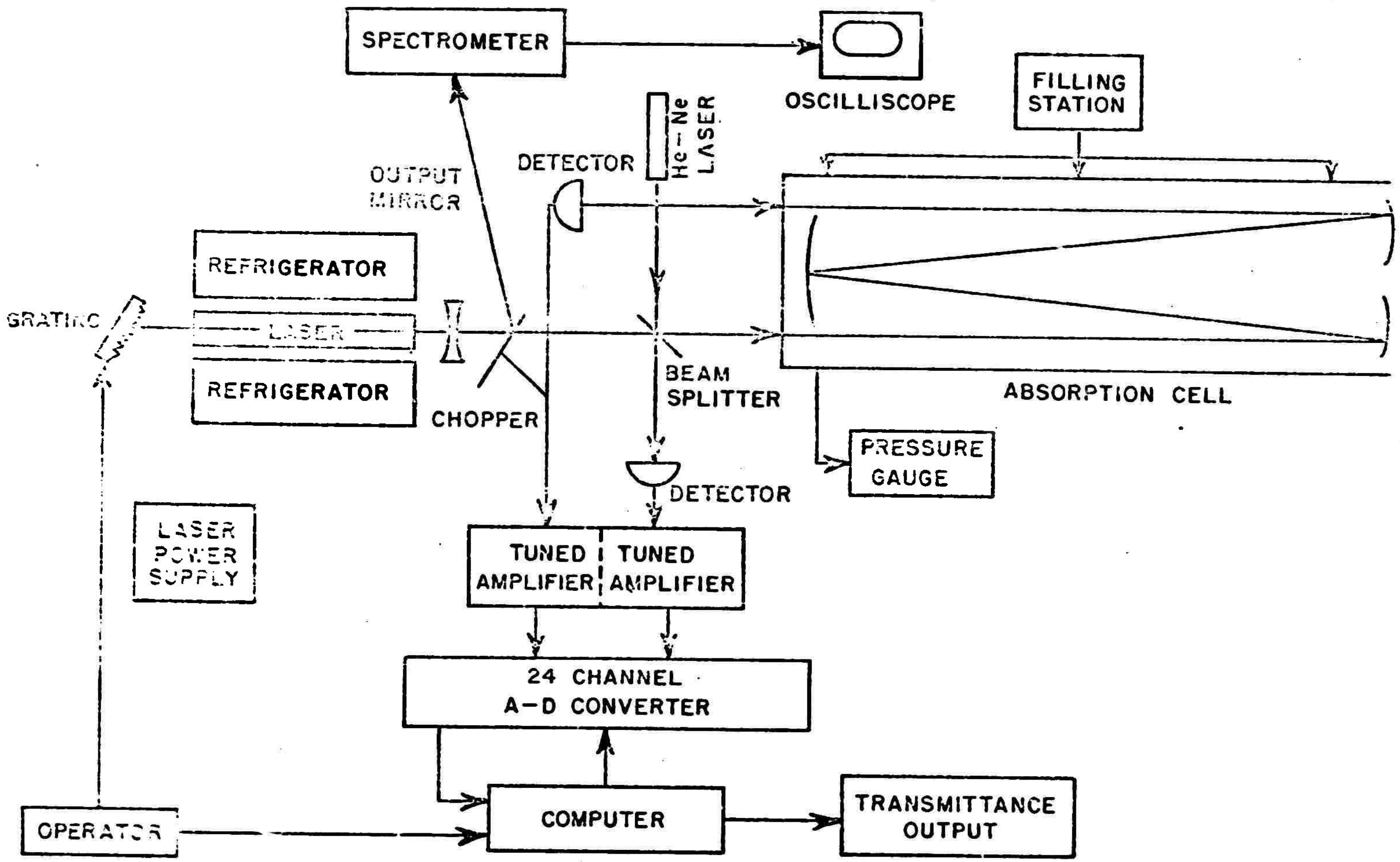

Fig. 4. Block diagram of the experiment.

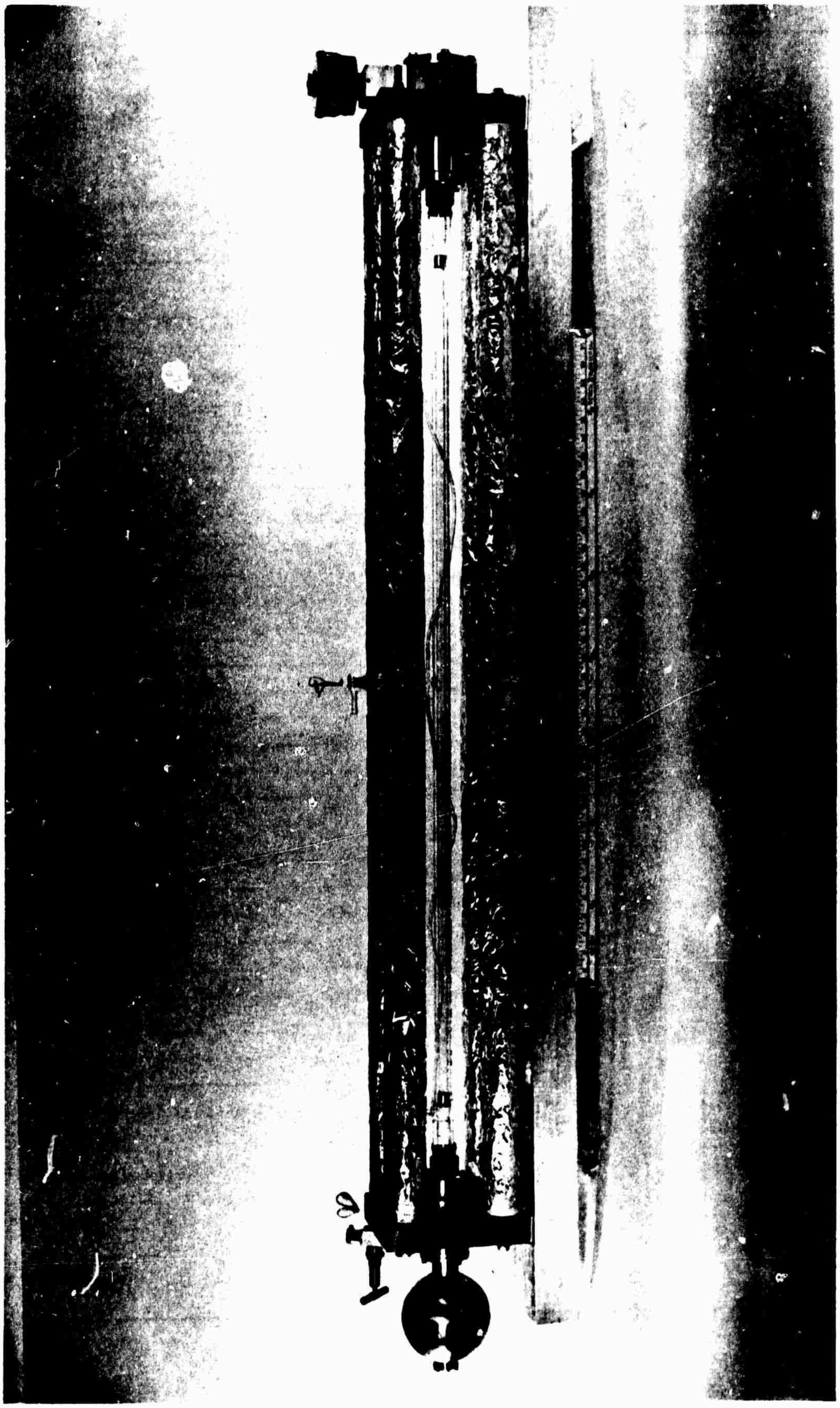

Fig. 5. The CO laser.

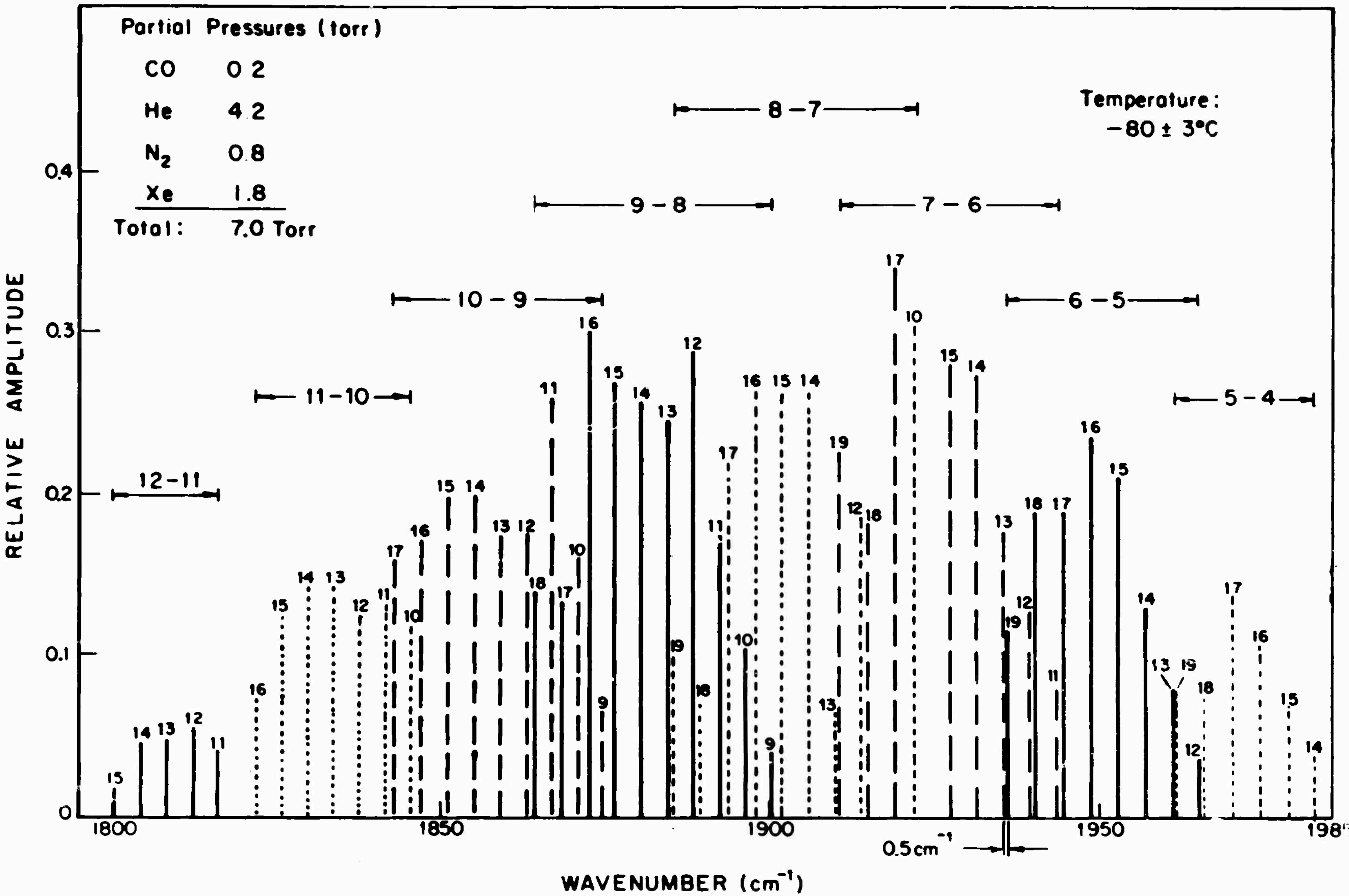

Fig. 6. Frequencies of the emission lines of a CO laser and their relative intensities.

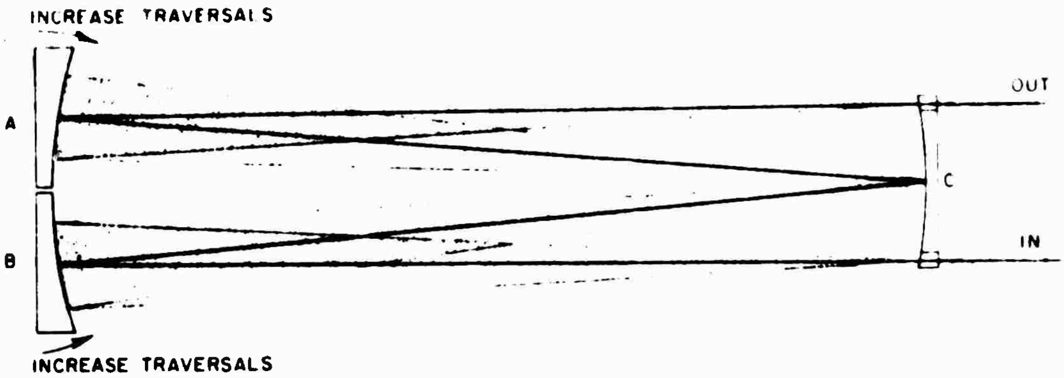

Fig. 7. Absorption cell ray diagram for four traversals.

A 100 cubic foot per minute mechanical pump and a six inch diffusion pump connected near the center of the cell by pneumatically operated valves are used to evacuate the cell to pressures as low as 10^{-4} torr.

The cell is filled through three ports. One port is located near the center and the other two near opposite ends. Copper pipe connected the three ports to a common valve manifold for metering the gases. The filling and evacuating lines are shown in Fig. 8.

The temperature of the cell may be raised as much as 20 degrees centigrade above ambient temperature. The inside of the cell is isothermal to within one half of a degree centigrade when the cell is at the maximum obtainable temperature. The higher temperatures allow a greater water vapor concentration to be placed in the cell without condensation appearing on the mirrors. For the CO laser lines appreciable absorptance occurs at the longer path lengths so that the cell will probably not have to be heated.

Detectors

The radiant flux from the CO laser will be incident upon three detectors as shown earlier in Fig. 4. Two of these detectors monitor the incident radiant flux on the absorption cell. One detector is part of a scanning spectrometer to ensure that the laser output is of a single frequency. We are currently evaluating several spectrometers to perform this function and provide an accurate calibration of the position of the grating of the CO laser. One of the other two detectors measures the intensity of the incident radiant flux, (the reference beam), onto the cell and the other detector, the intensity of the emerging flux. Tentatively these two detectors will be Cadmium Mercury Telluride, which have been bought, as they have a small time constant and a high detectivity at 5 μm and room temperature.

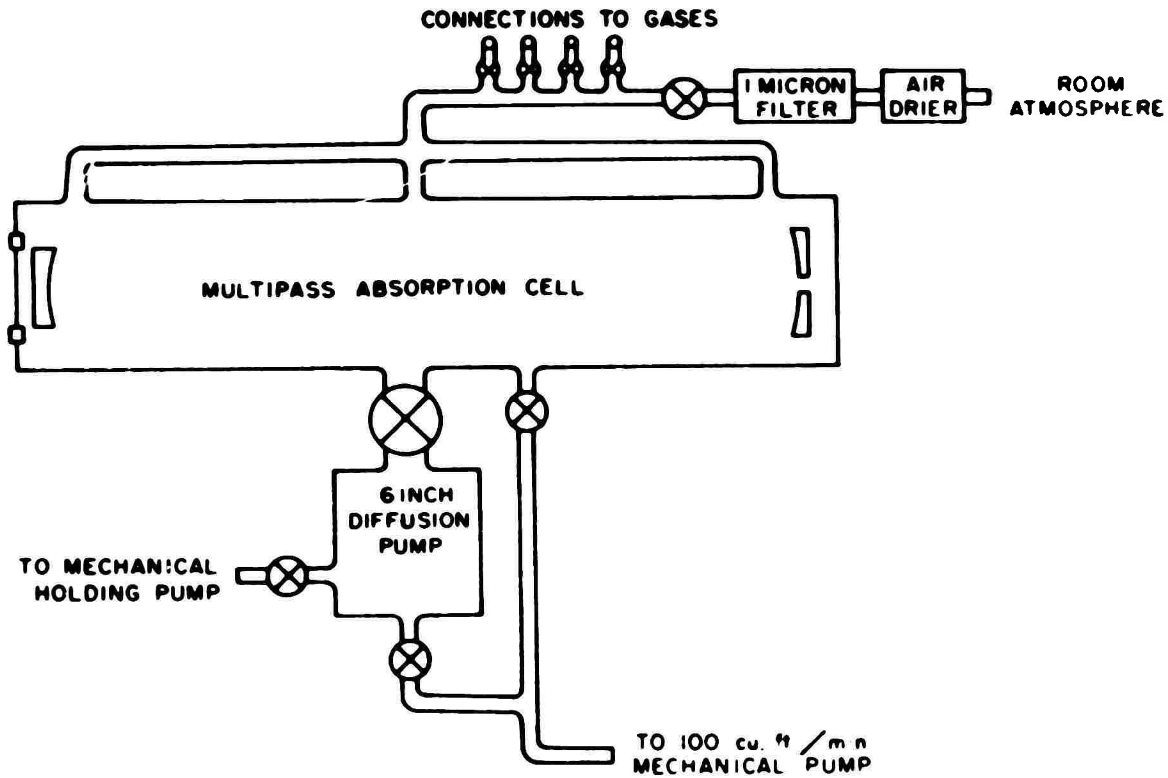

Fig. 8. Absorption cell filling and evacuating lines.

Data Handling

The signals from the two CMT detectors are converted to digital form and processed by an XDS 910 computer. By recording the output of both detectors with and without the absorber gas present in the cell the transmittance can be calculated for each of the selected laser lines. The transmittance T is given by

$$(10) \qquad T = \frac{(I_S/I_R)_{\text{absorber present}}}{(I_S/I_R)_{\text{cell evacuated}}}$$

where I_S and I_R are the intensities of the exit beam and the reference beam respectively. The low time constant ($\sim$.4 μs) and high detectivity of the CMT detectors permits a high data sampling rate so that in a shot time an accurate determination of the transmittance can be made for a given set of experimental conditions.

He-Ne Laser

The He-Ne laser shown in Fig. 4 is used to align the optics in the experiment.

Experimental

The procedure to determine the transmittance through water vapor-nitrogen mixtures at the frequency of each of the selected CO laser lines is described below. The output of the CO laser is calibrated with a spectrometer so that the frequency of the laser's output as a function of the reading on the micrometer, which controls the position of the grating, is known. Thus any particular line can be selected by positioning the grating correctly. The cell is evacuated to less than 10^{-2} torr. Then radiant flux of each of the desired frequency from the CO laser is transmitted through the absorption cell and the intensities of the incident and exit beams are measured. With this information the transmittance of the cell can be calculated. About 40 independent measurements are used to make this calculation. The output of the laser is also monitored with the scanning spectrometer to check that the laser is emitting a single frequency.

The cell is then connected to a bottle of distilled water which is heated several degrees centigrade above room temperature to speed evaporation. Too high a temperature will cause condensation to form in the cell and is to be avoided. The pressure of the water vapor in the cell is measured on a micrometric manometer which has previously been calibrated against a McCloud gauge using nitrogen. Several hours are required to fill the cell to the desired water vapor pressure. Dry nitrogen is then added to the cell to the desired pressure and allowed to mix for six to eight hours.

Once the mixture is uniform, the intensities of the entrance and exit beams are again measured and the transmittance is calculated from Eq. (10) by the on-line XDS 910 computer. The grating position is changed so that the transmittance of the next selected laser line is recorded. After all transmitting of the selected laser lines have been determined, the cell is evacuated, and the transmittance of the cell is remeasured at each selected laser frequency. If these values are not in good agreement with those obtained before the experiment, the experiment is repeated.

Optical path lengths, water vapor concentration, and total pressure are variables in the experimental program. The tentative range of these variables are shown in Table 5.

TABLE 5
RANGE OF EXPERIMENTAL PARAMETERS

Water Vapor Concentration	0.04 to 1.0 pr-cm
Optical Path Length	0.2 to 1.0 km
Total Gas Pressure	200 to 760 torr

IV. SUMMARY

A computer program has been written to calculate atmospheric molecular absorptance along horizontal paths at the frequencies of the output of a CO laser. Sample programs have been run corresponding to actual atmospheric conditions with water vapor and carbon dioxide being the absorbers. The form of the output can be either graphical, showing the transmittance as a function of frequency, or tabular, listing the transmittance at CO laser frequencies. Additional absorbers can be used as their molecular parameters are tabulated. Sample computer output are shown.

Another computer program has been written to calculate the atmospheric molecular absorptance along slant paths in the atmospheres for different atmospheric models. The standard atmospheric model for a 30°N latitude in July using H_2O as the absorber have been used, and sample pages of this computer output are shown.

These programs were originally written to run on the Ohio State University IBM 360/75 computer. Modifications to allow them to be run on the ElectroScience Laboratory Datacraft 6024/3 computer have been made.

A brief discussion of the design of the experiment for the determination of the transmittance of the CO laser emission lines through a multiple traversal absorption cell is described. Included are a description of the equipment and the procedure for making the measurements.

REFERENCES

1. Mantz, A.W., Nichols, E.R., Alpert, B.D. and Rao, K.N., J. Mol. Spec. 35, 325 (1970).

2. Yardley, J.T., J. Mol. Spec. 35, 314 (1970).

3. Benedict, W.S. and Calfee, R.F., Line Parameters for the 1.9 and 6.3 Micron Water Vapor Bands, Washington, D.C., U.S. Government Printing Office, (1967).

4. Deutschman, Elaine M. and Calfee, Robert F., "Two Computer Programs to Produce Theotretical Absorption Spectra of Water Vapor and Carbon Dioxide," ESSA, IER 31-ITSA 31, April 1967.

5. McCoy, John H., "Atmospheric Absorption of Carbon Dioxide Laser Radiation Near Ten Microns," Report 2476-2, 10 September 1968, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering; prepared under Contract F33615-67-C-1949 for Air Force Avionics Laboratory. (AD 839 938)

6. ESSA, U.S. Standard Atmosphere Supplement, 1966 Prepared under sponsorship of Environmental Science Services Administration, National Aeronautics and Space Administration, United States Air Force.

7. McClatchey, R.A., Fenn, R.W., Selby, J.E.A., Volz, F.E., and Garing, J.S., "Optical Properties of the Atmosphere," AFCRL-71-0279, Environmental Research Papers, No. 34, (1971).

8. Freed, C., private communication.

9. Long, R.K., "Absorption of Laser Radiation in the Atmosphere," Ph.D. Thesis, Department of Electrical Engineering, The Ohio State University (1963).